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AGE DETERMINATION IN BLACK BEARS FROM CANINE TOOTH SECTIONS[1]

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ABSTRACT

Stained sections from the canine teeth of 23 tagged wild black bears, considered known age and ranging from 1¾ to 5¾ years old, were studied for correlation with age. Microscopic examination showed cementum layering in exact agreement with the age at recovery for the bears tagged as cubs and in close agreement for those judged to have been yearlings when tagged. It was concluded that development of the canine teeth provides the most reliable method presently available for determining age in this species. Age assignments based on this method were made for 109 bears taken during the 1964 hunting season.

A reliable method of age determination is essential for successful management of any big game species because of the need for accurate yearly age classifications in understanding population dynamics. For the black bear (*Ursus americanus*) Stickley (1957) described an index of suture closure using nine major skull sutures. Application of this technique by Hewitt and Black (1959) to 17 skulls of known-age bears from zoos did not give satisfactory results, and they described a field technique for determining age by tooth wear based on the same skulls supplemented by specimens from autopsies and hunter kills. Their technique was used to separate bears into five age classes: Class I (cubs), Class II (yearlings), Class III (2+ to 4+ years), Class IV (5+ to 8+ years) and Class V (9+ years and older). Rausch (1961) was able to classify black bears in Alaska up to 6 years of age by counting

[1] A contribution of Federal aid in Fish and Wildlife Restoration Project W-89-R. The authors wish to thank William Hesselton and Eugene McCaffrey who helped with reading and interpreting the sections and in collecting specimens during the hunting season. Especial thanks are due William Goodrich of the New York State Health Department who suggested the hematoxylin-eosin staining technique, cut all the frozen sections and took photomicrographs of the transverse sections. The photograph constituting Figure 11 was made by N. Drahos.

annual rings laid down on the canine root until closure in the sixth summer. He correlated these annulations with layers in the dentine. These techniques proved inadequate for accurate age classification by year. Therefore, the possibility of using tooth-growth layers was explored. Pioneer studies by Scheffer (1950) and Laws (1952) were concerned with the dentine of marine mammals, and several others were concerned with growth layers in the cementum of thin tooth sections.

Sergeant and Pimlott (1959) found layering in the cementum of the first incisors of moose (*Alces alces*). They inferred that opaque cementum was laid down in the summer and fall and that translucent cententum was laid down in winter and spring. They were later able to confirm their suggested age scale with an incisor from a known-age 3½-year-old moose. Lack of agreement was found between ages assigned by the sectioning technique and those assigned by tooth wear for older age classes, and they concluded that the sectioning technique was more accurate.

Mansfield and Fisher (1960) found tooth layering in the cementum of a known-age captive harbor seal (*Phoca vitulina*). Counts placed the number of cementum layers at 18-20 and it was later learned that the animal was 19½ years old. They attributed the translucent layers to periods of minimal feeding during the breeding period and moult in spring and early summer.

Rausch (1961) found that, in sections of the canine teeth of bears, the cementum appeared as alternate dark and light layers which might be correlated with age. He found that these layers were often very difficult to count and did not attempt to use them in his work.

McEwan (1963) found a regular pattern of light and dark growth layers in the cementum of incisor teeth from barren ground caribou (*Rangifer tarandus groenlandicus*) that corresponded to one year less than the age of the animal.

Low and Cowan (1963) found layering in the cementum of the first incisor of the Columbian black-tailed deer (*Odocoileus hemionus columbiaus*). Using this technique together with known dates of birth and death, it was possible to estimate age to the nearest month.

Van Nostrand and Stephenson (1964) developed a technique for beaver (*Castor canadensis*) based on 42 known-age specimens. A combination of development and cementum layering in the cheek teeth was considered highly accurate in assigning yearly ages.

Mundy and Fuller (1964) found annuli in the cementum of the third molar of the grizzly bear (*Ursus* spp.) which seemed to be correlated with one year less than the age of the animal. They had no known-age specimens to test their hypothesis.

METHODS

To explore the possibility of using a tooth-section technique to determine the age of black bears, eight canines from specimens considered known-age were sent to the Fisheries Research Board of Canada where sectioning methods were being used to determine the age of harbour seals. Longitudinal sections made from these teeth showed evidence of layering in the cementum.

With this encouragement, the canine teeth from 38 bears considered known-age (23 wild and 15 captive) were selected for further study. The wild bears, which were collected in October or November during hunting seasons from 1956 to 1962, had been trapped, tagged and released as part of a program begun in 1956 by the Conservation Department as a contract project with Cornell University. Six had been tagged as cubs and 17 were judged to have been yearlings when tagged based on the tooth wear method of Hewitt and Black (1959). Ages at recovery ranged from 1¾ to 5¾ years. Recovery was encouraged by a cash reward for the return of the skull, tags and other information. The captive bears were animals 2¾ to 8¾ years old from various zoos in the State.

The canine teeth were removed from the skulls by boiling. Longitudinal sections were cut from the upper and lower left canines, as indicated in Figure 1, exposing for examination the cementum along the entire length of the root. They were polished to approximately 250 microns and stored in glycerine-alcohol to prevent splitting and curling. Several methods of lighting were tried for microscopic readings and a microprojector was also used to examine the sections.

The lower right canines were cut transversly at the widest part of the root (Figure 1) to see if the width of the pith cavity showed any correlation with age, and transverse sections about 3 to 5 millimeters thick were then cut from this part of each tooth. These sections were decalcified in 20 per cent formic acid for 2 to 3 days. From them, frozen sections approximately 25 microns thick were cut with a freezing microtome and stained with hematoxylin and eosin according to the following procedure:

1. Placed in Harris' hematoxylin for at least 1 minute.
2. Rinsed in water and placed in 100 milliliters of water with 3 to 4 drops amonium hydroxide until the section turned blue.
3. Rinsed in water and placed in eosin for ½ minute.
4. Rinsed in 95 per cent alcohol twice.
5. Dehydrated in absolute alcohol.
6. Cleared in xylene and mounted wet.

These sections were examined microscopically at magnifications of 40X and 100X with transmitted light.

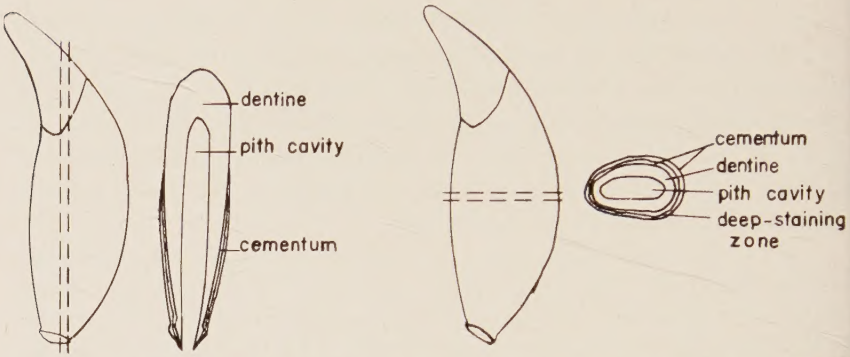


Figure 1. Location and appearance of longitudinal (left) and transverse (right) sections of canine tooth of black bear. Cementum portion deliberately exaggerated for purposes of diagram.

Canine teeth were collected from 109 bears of unknown age killed by hunters during the 1964 big game season. Transverse sections of these teeth were obtained according to the foregoing procedure.

FINDINGS

In both the longitudinal and transverse sections from the canines of the captive bears, layering was generally faint or entirely absent and no accurate age determinations could be made. In one male known to have been 8¾ years old, a single wide layer of cementum was present. Data from these specimens were discarded and no further use was made of the teeth of captive bears.

In the 250-micron longitudinal sections of canines from the wild bears, alternate opaque and translucent layering was apparent in the cementum, but no corresponding layers could be found in the dentine. Under a microscope, polarized light gave the most satisfactory interpretations; however, projection of the sections with a microprojector was considered superior. Thus projected, it was possible for several observers to see simultaneously the criteria being considered and discuss variations and differences in interpretation.

In the cementum of the 25-micron transverse sections, wide light-staining layers were separated by narrow deep-staining bands in the teeth from the wild specimens. As an hypothesis, each successive dark band was considered to represent an added year of life. Under a microscope, interpretations could be made satisfactorily at magnifications of 40X or 100X without polarized light. Two observers making independent interpretations were in agreement on the ages of 21 specimens and only 1 year apart on the two others.

The estimated ages as derived from the two types of tooth section for each specimen are compared in Table 1 with that based on the

TABLE 1. COMPARISON OF ESTIMATED AGE AS DERIVED FROM TOOTH SECTIONS WITH THAT BASED ON DENTITION AND SIZE AT TIME OF TAGGING FOR 23 WILD BEARS TAGGED AS CUBS OR YEARLINGS

Specimen no.	Sex	Age at recovery*	Estimated age as derived from tooth sections	
			Longitudinal section	Transverse section
Cubs when tagged				
B 262	Male	1¾	1¾	1¾
B 307–308	Female	1¾	1¾	1¾
B 617–618	Male	1¾	1¾	1¾
B 24–27	Female	4¾	4¾	4¾
B 505–506	Female	4¾	4¾	4¾
B 23–25	Male	5¾	5¾	5¾
Judged to have been yearlings when tagged				
B 396–397	Male	1¾	1¾	2¾
B 735–736	Female	1¾	2¾	2¾
B 739–740	Male	1¾	1¾	2¾
B 774–775	Female	1¾	1¾	1¾
B 861–862	Male	1¾	1¾	1¾
B 52–53	Female	2¾	3¾	4¾
B 340–341	Male	2¾	3¾	3¾
B 439–440	Male	2¾	1¾	1¾
B 701–534	Male	2¾	3¾	3¾
B 722–723	Male	2¾	2¾	3¾
B 726–727	Female	2¾	2¾	2¾
B 257–276	Male	3¾	3¾	3¾
B 285–286	Male	3¾	3¾	3¾
B 361–400	Female	3¾	3¾	3¾
B 448–450	Male	3¾	3¾	3¾
B 826–827	Male	3¾	2¾	3¾
B 55–56	Female	5¾	4¾	5¾

* Represents sum of age when tagged and elapsed time between tagging and recovery; in some instances, bears judged to have been yearlings when tagged may actually have been older (see text).

dentition and size of the animal when it was tagged and the elapsed time between tagging and recovery. All were in exact agreement for the bears tagged as cubs. For those judged to have been yearlings when tagged, the age as estimated from the longitudinal sections agreed with the assumed actual age for 10 of the 17 specimens; four were overestimated by 1 year and three were underestimated by 1 year. Those estimated from the transverse sections agreed for nine specimens; one was overestimated by 2 years and six by 1 year, while one was underestimated by 1 year.

At the time the bears were tagged there could be no question as to which were cubs. There is reason to believe, however, that some

of those considered to have been yearlings were actually older. But, in any case, none was younger than the age assigned to it. Therefore, any interpretations from the tooth sections that gave a younger age were incorrect.

With respect to the bears considered to have been yearlings when tagged, the ages derived by the two sectioning methods were in agreement for 11 of the 17 specimens. In each case where discrepancies occurred, the age based on the transverse section was 1 year greater than that based on the longitudinal section. The age of specimen B-439-440 was consistently underestimated by both methods. Therefore, on the basis of present knowledge, an allowance of ± 1 year is considered necessary for age assignments made from tooth sections for animals older than 1 year. The fact that seven of the 17 bears were judged older, according to the transverse sections, than the estimated age at recovery is a strong indication that toothwear characteristics as presently recognized are an inadequate basis for separating yearlings from older animals.

The 25-micron transverse sections were considered superior to the 250-micron longitudinal sections for accurate determination of annual growth layers in the cementum. The thickness of the 250-micron sections made interpretation of the growth layers difficult, especially for 2¾-year-old and older bears, and underestimation of age was probably due to the optical properties of the thick section. Interpretation of the 25-micron sections was based on the histological structure of the cementum and was highly objective. Photomicrographs of representative transverse sections for bears from 1¾ to 5¾ years of age[2] are shown in Figures 2 to 6.

As interpreted from transverse tooth sections, the age of the 109 bears taken by hunters in 1964 ranged from 1¾ to 25¾ years (Table 2). Three observers making independent interpretations were in exact agreement on 71 specimens (65 per cent). They were 1 year apart for 19 specimens (18 per cent), 2 years apart for eight (7 per cent), and more than 2 years apart for 11 (10 per cent). All except one of the last 11 specimens were 9¾ years old or older. A consensus was reached on these 38 specimens by use of a 6-inch viewing screen attachment for the microscope which enabled all three observers to discuss differences in interpretation and decide on a single age designation in each case. Presumably, this group of bears was a random sample. Yet, in relation to the number of yearlings and 3¾ year olds, the number of 2¾ year olds was disproportionately small. No expla-

[2] These and most other speciments represented bears taken during fall hunting seasons; they had thus completed about three-quarters of their last year of life. Throughout the paper this fraction is used to denote the age of such specimens.

TABLE 2. AGE DISTRIBUTION OF 117 BLACK BEARS TAKEN DURING THE 1964 HUNTING SEASON IN NEW YORK

Age in years	Number		
	Adirondack region	Catskill region	Allegany County
1¾	43	1	2
2¾	4	..	..
3¾	20	..	..
4¾	11	2	..
5¾	3	1	..
6¾	6	..	..
7¾	1	1	..
8¾	1	..	..
9¾	5	..	..
10¾	3	..	..
11¾	3	..	..
12¾	1	..	..
13¾	4	..	..
14¾	..	..	..
15¾	1	..	..
16¾	1	..	..
17¾	..	..	..
18¾	..	..	..
19¾	..	..	..
20¾	..	..	..
21¾	1	..	..
22¾	..	..	..
23¾	..	..	..
24¾ ±2	1	..	..
25¾ ±2	1	..	..
Total	110	5	2

nation can be offered for this, and the authors do not believe that an imperfection in the sectioning technique was responsible.

The width of the cementum and the appearance of growth layers varied considerably in different parts of a transverse section. The cementum was widest in the area that would constitute the upper and outer edges of the tooth root *in situ* and growth layers were best defined in this area. As the cementum became more compact in the area that would be the lower and inner edges of the root, growth layers were deposited closer together. For this reason, separate layers could not be traced around the entire tooth section for animals older than about 5 years.

Interpretation of growth layers was not always simple. Usually they were uniformly wide for about 5 years and uniformly narrow after that. Representative tooth sections of animals judged to have been 10¾ years and 21¾ years old are shown in Figures 7 and 8. Occasionally, uneven layering occurred in the outer growth layers of the teeth of older animals. Figure 9 shows a tooth section from an animal that could have been from 22¾ to 26¾ years old depending

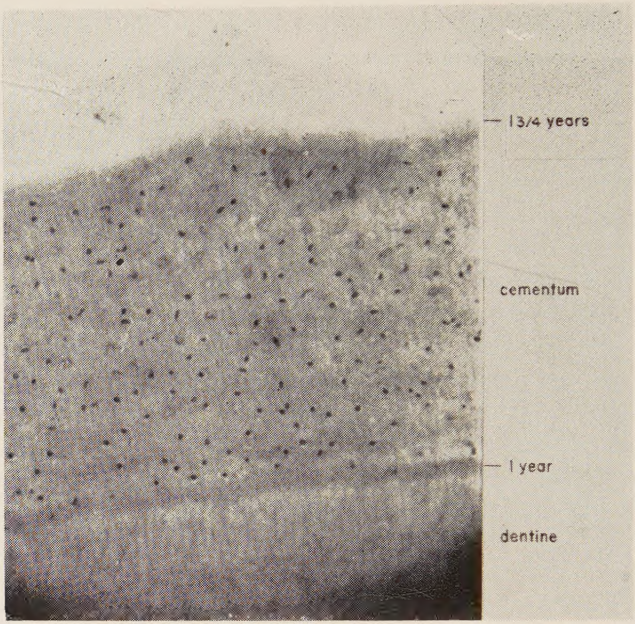


Figure 2. Segment of cross section of canine tooth (×62.5) from 1¾-year-old black bear showing single layer of cementum present at this age. Dark-staining objects are cell nuclei.

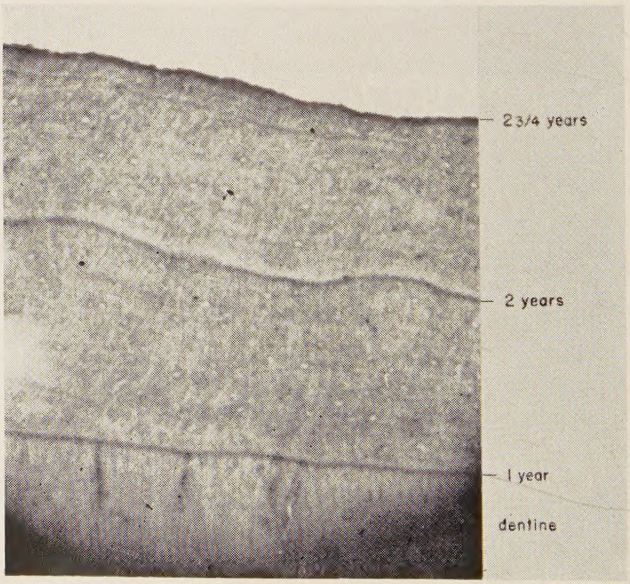
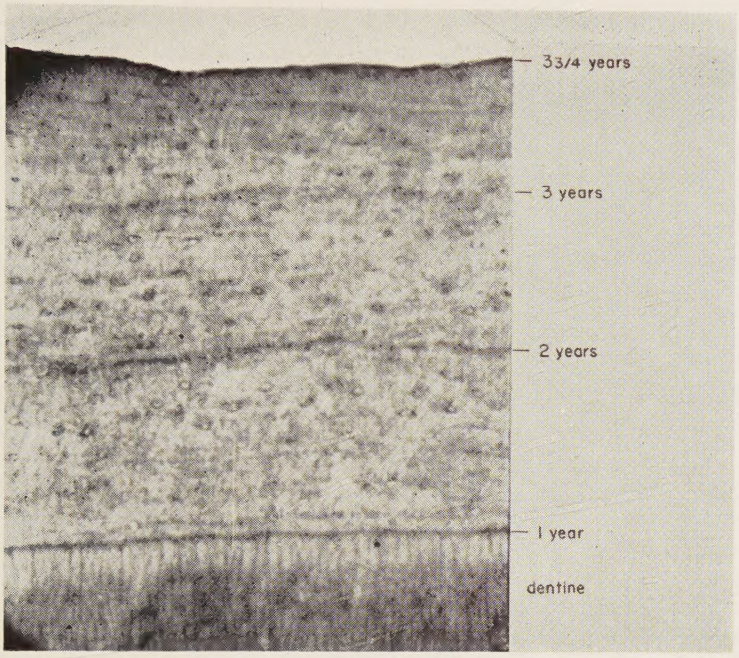
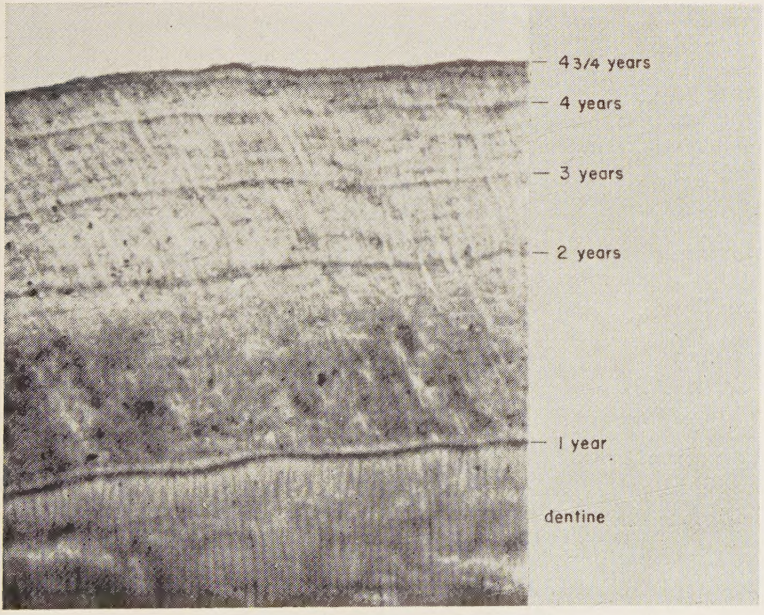


Figure 3. Segment of cross section of canine tooth (×62.5) from 2¾-year-old black bear showing two growth layers separated by dark-staining layer deposited during intervening winter.



igure 4. Segment of cross section of canine tooth (×62.5) from 3¾-year-old black bear.



igure 5. Segment of cross section of canine tooth (×62.5) from 4¾-year-old black bear.

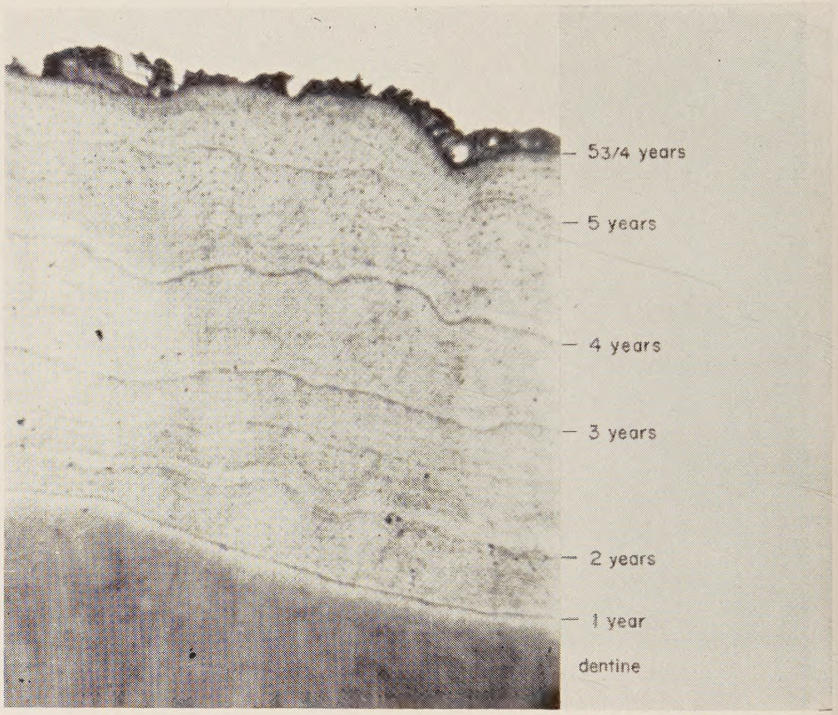


Figure 6. Segment of cross section of canine tooth (×31.2) from 5¾-year-old black bear.

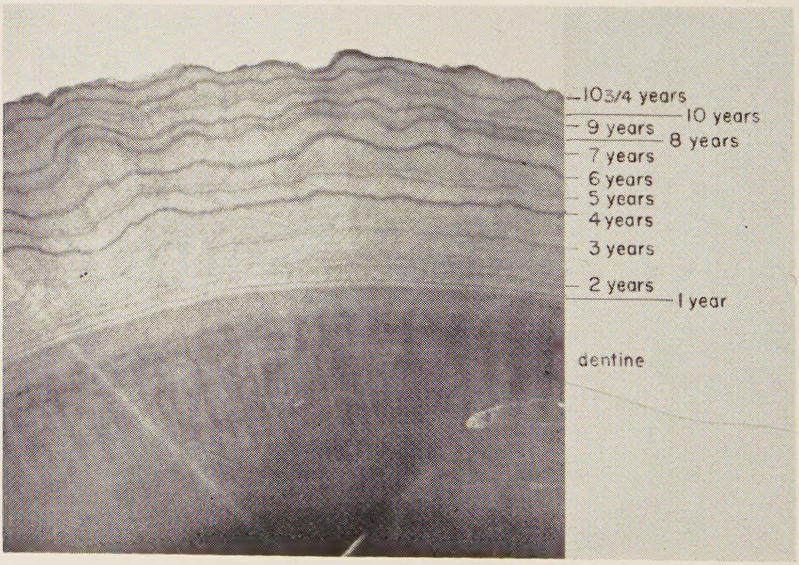


Figure 7. Segment of cross section of canine tooth (×6.2) from a black bear judged to have been 10¾ years old.

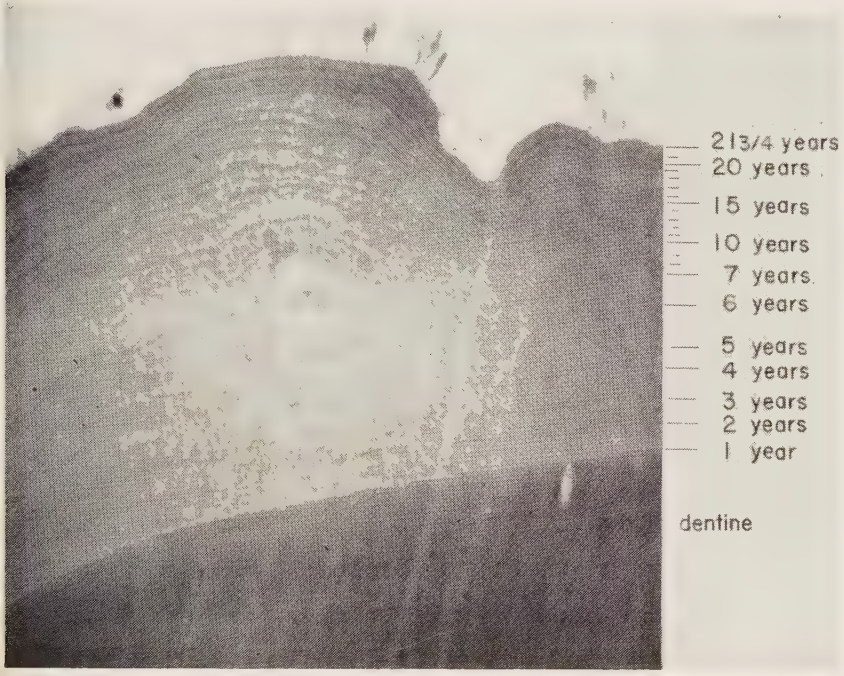


Figure 8. Segment of cross section of canine tooth (×6.2) from a black bear judged to have been 21¾ years old. The layers representing 6 and 7 years illustrate the occurrance of false separating zones that sometimes appear in one part of a section but are found to disappear when the layer is traced farther around the tooth.

on interpretation of various narrow layers that were present. This difficulty cannot be resolved until uneven layering is viewed in older known-age animals. Sometimes interpretation was confused by false separating zones that appeared and faded within single growth layers (Figure 8).

When the width of the pith cavity was plotted against the age estimates made from cementum layer counts in transverse sections for the 23 known-age specimens (Figure 10), differences between yearlings, 2¾ year olds, and older bears became apparent. These differences in the width of the pith cavity corresponded to differences in gross appearance (Figure 11). The roots of the canine teeth of all six yearlings were open. Those of the four 2¾ year olds had a constriction near the base and one annulation indicating where growth had stopped the previous winter, but the roots remained open. Those of the 13 bears 3¾ to 5¾ years old were closed but the pith cavities remained open.

Furthermore, all 44 yearlings in the sample from the 1964 hunting season had open canine roots. Only five 2¾ year olds were rep-

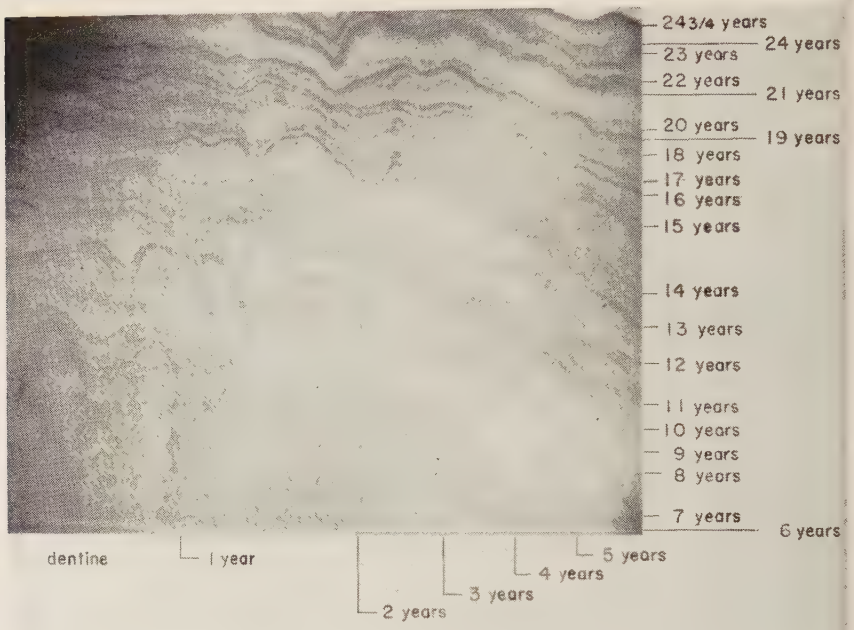


Figure 9. Segment of cross section of canine tooth (×6.2) from a black bear judged to have been 24¾ ±2 years old.

resented in this sample; in four cases the teeth corresponded in gross appearance to those of the known-age specimens of that age, while the root of the fifth was closed. However, teeth from two of 18 bears 3¾ years old also had the gross appearance of those of the 2¾ year olds. Therefore, more material is needed to determine the exact time of root closure.

DISCUSSION

In summary, the ages of bears can be determined from the development of the canine teeth (Figure 11). Cubs can be recognized by their deciduous dentition until the permanent canines erupt during their first fall. Stickley (1957) working with three captive cubs found that the permanent upper canines erupted during November or December of the bear's first year and the lower canines during January. Rausch (1961) placed eruption of the permanent canines during October based on 31 skulls from Alaska. The permanent canines of bears less than a year old can be recognized by their extremely short roots.

Yearlings can be separated by the open root of these teeth and the classification may be verified by examining the cementum in trans-

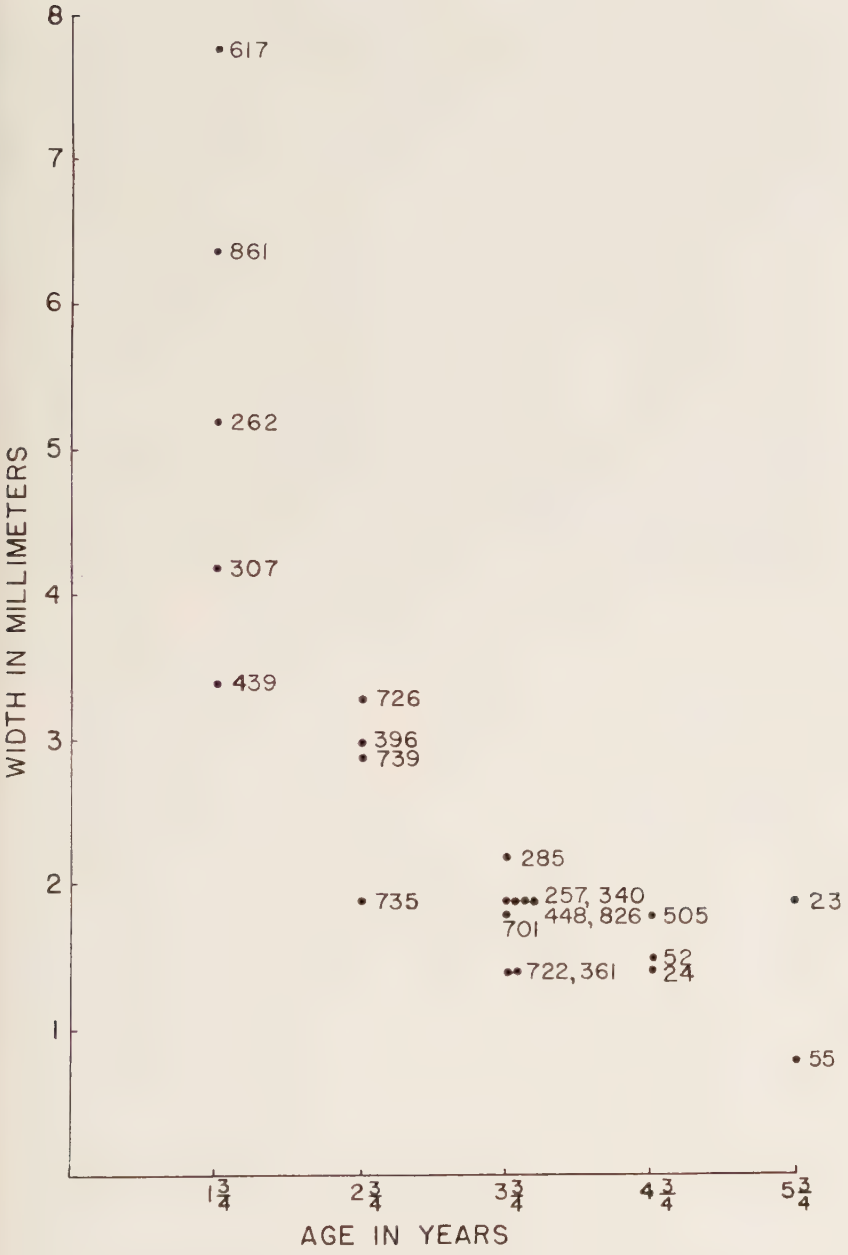


Figure 10. Width of pith cavity in relation to age for 23 wild black bears. (Numerals refer to individual specimens as listed in Table 1).

verse sections. Deposition of the first layer of cementum probably takes place during the second summer of the bear's life, so one wide

Figure 11. Gross appearance of the canine teeth of black bears at (from left) 9 months, 1¾ years, 2¾ years, 3¾ years, and 25¾ ±2 years of age. Until it closes, the shape and width of the root opening indicates the age of the animal.

light-staining layer is present at this time. To date, all canines of yearlings (50) have corresponded to the gross appearance shown in Figure 11, and this characteristic alone is considered a reliable criterion for this age.

The ages of bears 2¾ years old and older can be determined from the annular layering in the cementum. The first deep-staining band probably appears during the second winter and represents 2 years of age. Deposition of cementum radially from the dentine continues throughout the bear's life, each subsequent wide layer and narrow dark band representing an additional year.

It is felt that captive bears differ too greatly from wild bears in tooth development for data from them to be considered. Rausch (1961) reported striking differences in growth patterns between captive and wild bears; the captive animals were consistently more mature in bone structure and dentition at comparable ages. Although captive bears may not have regular denning habits, Rausch felt that nutrition was the major factor in this accelerated growth rate. The canine teeth failed to develop annulations correlated with denning periods in some of his captives. The cementum would doubtless be affected for the same reasons.

The technique used by Rausch for wild bears, which was based on annulations correlated with layers in the dentine, cannot be used

in New York because of the difference in time of root closure. He found that the roots of the canines of black bears from Alaska did not close until the sixth summer. Specimens from New York indicate root closure between the third and fourth summers. This earlier closure accounts for the lack of annulations and lack of layering in the dentine. The cessation of dentine deposition after root closure has been reported for seals (Carrick and Ingham, 1962) and for humans (Nonidez and Windle, 1949).

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DETERMINING SEX OF BLACK BEARS FROM THE SIZE OF THE LOWER CANINE TOOTH[1]

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ABSTRACT

Data for 154 black bears of known sex from the Adirondack region showed that the canine teeth from males were significantly larger than those from females for the five dimensions measured and for volume. Maximum root width and maximum root thickness were the best criteria of sex, and, using them with respect to the lower canines, 78 of 78 females (100 per cent) and 70 of 74 males (95 per cent) were classified correctly. A gauge was devised with which about two-thirds of the sample could be sexed without individual tooth measurements.

Lower canine teeth of black bears (*Ursus americanus*) taken by hunters were collected during the 1964 and 1965 big game seasons for age classification by a tooth-sectioning technique (Sauer *et. al.*, 1966). In preparing these specimens, it became apparent that the sex of a bear could generally be determined by the size of its canine teeth. To determine which dimensions would be the best criteria, further investigation was undertaken. Knowledge of age composition by sex is necessary for proper management of bear populations. Hunter reports are not always reliable, and few bears are examined by Department technicians in any one year. A reliable method of sexing based on a skeletal part such as the tooth, which could be collected from hunters, would greatly increase the usefulness of data on age distribution.

Canines were available for measurement from 154 bears of known sex from the Adirondack region, 75 males and 79 females, that were collected from 1956 through 1965. Of these, 57 were from bears that had been autopsied during trapping and tagging operations, 54 were from bears that had been sexed when tagged and were later taken by hunters who returned the tag with the skull or lower jaw, and 43 were from hunter-killed bears that had been examined by Department technicians. All were considered correctly sexed.

PROCEDURE

The lower canine teeth were used because successful hunters are asked to contribute the lower jaws of their bears for age assignment. The teeth were removed from the jaws by boiling. Where possible,

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R. The author is grateful to C. W. Severinghaus for helpful comments on the manuscript and the original idea of a gauge, to Stuart Free for reviewing the manuscript and improving the gauge, to Ralph Turmel for constructing the gauge described and to Dr. Lawrence Mason of the State University of New York at Albany for reviewing the statistical treatment of the data.

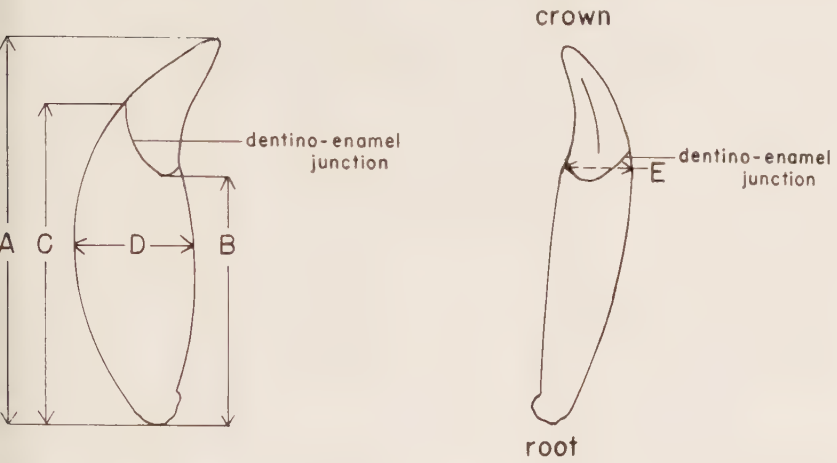

Figure 1. Measurements made of lower canine teeth of black bears: A—total length; B—minimum root length; C—maximum root length; D—maximum root width; E—maximum root thickness.

The following five dimensions were measured; their locations are shown in Figure 1.

1. Total length: from the tip of the crown to the tip of the root (to the nearest millimeter).
2. Minimum root length: from the lowest edge of the dentino-enamel junction to the root tip (to the nearest millimeter).
3. Maximum root length: from the highest edge of the dentino-enamel junction to the root tip (to the nearest millimeter).
4. Maximum root width: (to the nearest 1/10 millimeter).
5. Maximum root thickness: just below the dentino-enamel junction (to the nearest 1/10 millimeter).

These measurements were taken only for bears more than a year old. Only four cubs of known sex were available, and, since the permanent canines of cubs have extremely short, wide, open roots which are not adapted to such measurement, no attempt was made to apply the technique to them. Ages were determined by the tooth-sectioning technique described by Sauer *et. al.* (1966).

Volume was also determined to the nearest milliliter by displacement of water for whole canines of bears more than 2 years old. It was not taken for teeth from cubs and yearlings because in such specimens the root is open and would collect water.

For 14 specimens, minimum root length and maximum root width were compared for an upper and lower canine. These were the only two comparable dimensions recorded for the upper and lower canines before the teeth were sectioned.

For all measurements, differences between the means for males and females were compared by a *t*-test.

FINDINGS

The measurements are summarized in Table 1. The canines from males were significantly larger than those from females (at the 1 per cent level of confidence) for all dimensions except minimum root length in age group 1.

The least overlap between males and females occurred in the measurements of maximum root width and maximum root thickness. Dividing points at 16.7 millimeters for maximum root width

Table 1. Mean Dimensions of Lower Canine Teeth of Black Bears from the Adirondack Region

Measurement	Age group*	Number	Mean dimension§	Standard error	Range
Female					
Total length	1	7	49	1.1	45–52
	2 and older	17	56	0.7	52–62
Minimum root length	1	7	25	1.5	17–28
	2 and older	20	32	0.5	29–36
Maximum root length	1	..	..	..	..
	2 and older	11	43	0.9	38–46
Maximum root width	1 and older	67	15.0	0.1	12.6–16.8
Maximum root thickness	1 and older	76	9.2	0.1	8.2–10.2
Volume	2 and older	12	4	0.2	3–5
Male					
Total length	1	8	56	0.7	54–60
	2 and older	28	65	0.7	57–71
Minimum root length	1	9	29	0.7	26–32
	2 and older	29	38	0.6	31–43
Maximum root length	1	6	43	1.4	37–47
	2 and older	19	52	0.6	46–56
Maximum root width	1 and older	63	18.8	0.2	14.8–21.7
Maximum root thickness	1 and older	71	11.4	0.1	8.8–13.7
Volume	2 and older	20	7	0.3	5–10

* Age group 1 represents all fractional ages between 1 and 2 years.
§ In millimeters, except volume in milliliters.

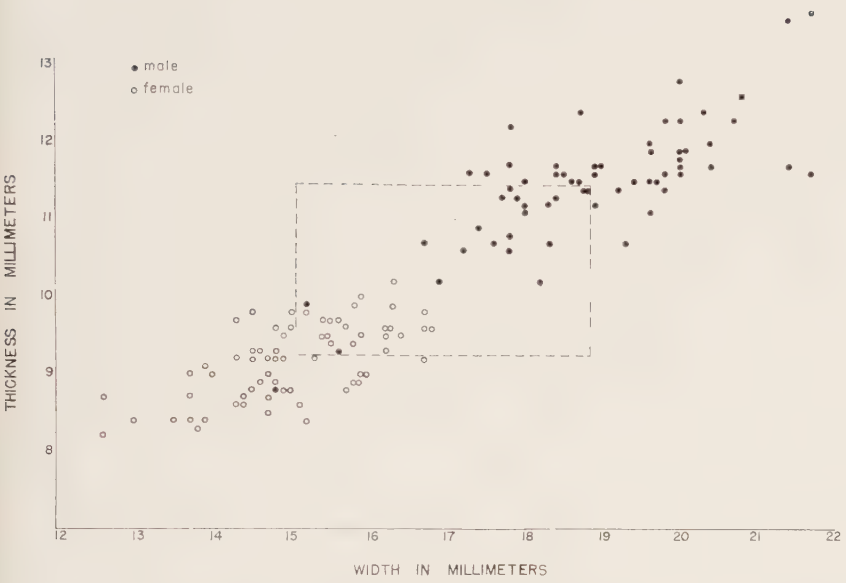

Figure 2. Relationship of maximum root width to maximum root thickness for the lower canine teeth of black bears. Teeth represented by symbols outside the inner rectangle could be accurately sexed with the gauge. Only those inside the rectangle would have to be measured individually to determine the sex of the animal.

and 10.2 millimeters for maximum root thickness separated most of the sample into the proper sex (Figure 2). There was an overlap in width between one male and four females and an overlap in thickness between three males and one female. Therefore, when either measurement approached the dividing point, the two were added together. The total of maximum root width plus thickness for the largest female was 26.5 millimeters so this was considered the upper limit for females. The total for the smallest male showing no overlap with that for a female was 27.1 millimeters so this was considered the lower limit for males. For totals between 26.5 and 27.1 millimeters no sex can be designated until these values are observed in animals of known sex.

These criteria were then applied to 152 of the specimens in the sample; for one male and one female the data were insufficient for this purpose. Using the individual dividing points for maximum root width or maximum root thickness, or those for the two measurements combined, all 78 females and 70 of 74 males (95 per cent) were correctly sexed. For the four males incorrectly sexed, the combined measurements (23.6, 24.9, 25.1 and 25.5 millimeters) were well below the limit established for females. Three of these males were in age group 3, and one was in age group 4.

The combined measurement for the oldest male (age group 32) and that for the oldest female (age group 20) were 32.1 and 24.5 millimeters, respectively. For the largest canine from a male (age group 25) and for the largest canine from a female (age group 4) it was 35.4 and 26.5 millimeters, respectively.

The volume of the lower canines also provided an accurate separation between males and females; however, the sample size was small. The only overlap occurred at 5 milliliters between adult females and males in age group 2. Thus a volume of 4 milliliters or less would indicate a female. A volume of 5 milliliters would indicate a female if the root was closed or a male in age group 2 if the root was open. A volume of 6 milliliters or more would indicate a male. If volume were taken to the nearest 1/10 milliliter a more definite separation might be possible between males in age group 2 and females of that age or older.

In comparing 14 sets of upper and lower canines, minimum root length of the upper teeth was greater in all cases, while maximum root width of the upper teeth was greater in six cases and smaller in one. The upper canines averaged 6 millimeters larger in minimum root length and 0.4 millimeter wider in maximum root width.

DISCUSSION

This technique was applied to canines from bears of unknown sex taken in the Adirondack region during the regular hunting season. For the 1964 season, 44 animals were sexed as males, 33 as females and 2 were indeterminate. For the 1965 season, 41 were sexed as males, 42 as females and 3 were indeterminate. The technique should also be valid for black bears from other ranges once appropriate measurement limits have been established.

Sexual dimorphism in the dentition of adult black bears from Alaska was noted by Rausch (1961). Measurements of maximum length and of maximum transverse diameter of the upper canines showed overlaps between the sexes of 1 per cent and 3 per cent, respectively. For males and females mean length was 73.0 and 60.7 millimeters, respectively; and mean transverse diameter was 12.0 and 9.8 millimeters, respectively. Since these data represent upper canines, they cannot be compared with those determined in the present study.

A gauge by which the sex of at least part of a sample of bears could be determined accurately from their canine teeth would save considerable time and would also be more exact than individual measurements for each tooth. A gauge incorporating measurements for both maximum root width and maximum root thickness for each sex and set exactly at the means shown in Table 1 should make it possible to identify half the males and half the females. Such a gauge

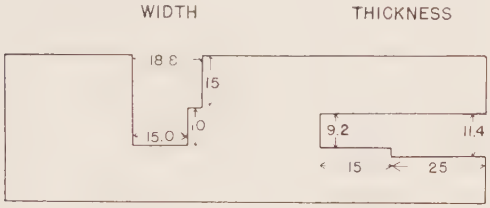

Figure 3. The gauge devised for sexing black bears by the size of the lower canine tooth. It indicates sex as follows.

Female: tooth fits into smaller part of slot for either width or thickness (but not necessarily both).

Male: tooth does not fit into larger part of slot for either width or thickness (but not necessarily both)

If tooth fits into the larger part of both slots, but into the smaller part of neither, it must be measured and a summation of the width and thickness made as described in the text.

is illustrated in Figure 3 and is easily constructed. Accuracy to the nearest 1/10 millimeter is important.

Using mean values for gauge size essentially assures absolute accuracy with respect to females because for neither width nor thickness do three standard deviations from the mean overlap the mean for males. However, in the case of males, three standard deviations from the mean just overlap the mean for females, so there is about 1 chance in 300 of a tooth from a male fitting either part of the gauge applying to females.

Actually the gauge separates the sexes for more than half the animals in a sample. A tooth must measure less than the mean for females in only one dimension to be sexed accurately as a female, or greater than the mean for males in only dimension to be sexed accurately as a male. A scatter diagram of width and thickness (Figure 2) shows that only teeth whose dimensions are larger than both means for females or smaller than both means for males would have to be measured other than with the gauge. In this sample, 88 of 130 specimens (68 per cent) would be classified properly by the gauge.

Because all the specimens from which these data were derived came from the Adirondack region, the specific measurements developed as criteria of sex may or may not be valid in areas where environmental conditions are different.

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FACTORS AFFECTING FIRST-YEAR GROWTH OF WALLEYES IN ONEIDA LAKE, NEW YORK[1]

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ABSTRACT

First-year growth of walleyes was determined from samples taken by seining and trawling at about weekly intervals in the summers of 1956 through 1964. Rate of growth in length gradually increased until walleyes reached a length of about 20 millimeters during the first or second week in June. In most years weekly growth increments from mid-June to mid-August were relatively constant, and growth rate decreased rapidly in September. Although population mean lengths increased between late fall and the following spring, this increase was probably caused by selective mortality of smaller walleyes in a year class rather than growth during winter.

Length attained by July 1 was closely correlated with May-June air temperatures, but growth increments between July 1 and September 1 were not directly dependent on the air temperature regime in July and August. Growth rate in late summer tended to be rapid in years when walleyes fed on fish and lower when invertebrates were common in the diet. Although yellow perch were the principal forage fish found in walleye stomachs, growth in summer was not correlated with density of young perch.

In Oneida Lake the walleye (*Stizostedion vitreum*) spawns in April and eggs hatch during the first or second week in May. Fry are pelagic until reaching a length of 25-30 millimeters. Concentrations of fry are found in bays where they remain near the surface during daylight hours. Juveniles are abundant along the shoreline during late June and early July. During summer there is a gradual offshore movement and by October most young are found at depths of 20 to 40 feet. From 1956 to 1964 samples of young were collected to examine yearly variation in diet and growth rate.

Smith and Pycha (1960), working on the Red Lakes in Minnesota, found some evidence that the length of walleyes at the end of the first year varied directly with summer temperatures and inversely with the size of young yellow perch. Maloney and Johnson (1957) observed a close ecological association between young walleyes and yellow perch and suggested that the size and abundance of yellow perch may be an important factor in determining year-class strength of walleyes. Although other authors (Eschmeyer, 1950; Raney and Lachner, 1942) have noted the importance of young perch in the diet of walleyes, the effect of yellow perch abundance on walleye growth has not been thoroughly examined.

Oneida Lake has an area of 80 square miles and a maximum

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depth of 55 feet. Morphological and limnological features of the lake were described by Adams and Hankinson (1928) and more recently by Mt. Pleasant *et al.* (1962). Oneida Lake is generally homothermal in summer although temporary stratification may develop during periods of prolonged calm weather. The walleye is the most important sport fish. Its year-class strength has fluctuated widely during the past decade, but the growth rate of adult walleyes has remained relatively stable over a 20-year period (Forney, 1965).

This paper describes the first-year growth of walleyes during the period 1956 to 1964 and its relation to the annual air temperature regime and forage fish density.

SAMPLING METHODS

Samples of young walleyes were taken with meter nets of #00 nylon mesh in May and with a 7-foot square, midwater trawl during early June. Collections in summer and fall were made by shore seining and trawling. Bag seines were 75 feet long and constructed of ¼-inch woven nylon netting. Trawl collections were made in water 15 to 40 feet deep with an 18-foot flat otter trawl with ½-inch square mesh in the body and ¼-inch mesh in the cod end. Some escapement of small walleyes through the ¼-inch mesh of seines and trawls occurred in June, but by the second week in July all walleyes were large enough to be retained.

Collections by seining or trawling were made at intervals of about one week from late June through October in the years 1958 to 1964. In 1956 and 1957 samples were taken less frequently and all fish were collected by shore seining. Total length was measured in millimeters and all measurements were taken on fish preserved in formalin. Scales of larger walleyes were often examined to determine age since there was some overlap in length among 0+ and 1+ fish in late summer.

Estimates of Mean Length

Samples collected in June and July consisted chiefly of walleyes taken in seines while most walleyes measured in late summer were collected by trawling. Mean lengths of specimens taken on the same date by seining along shore and by trawling in deeper water were often significantly different. In most years those caught in seines tended to average longer than those taken by trawling in July, but in late summer the larger fish were generally taken by trawling (Figures 1, 2 and 3). Since there was no rational basis for differentially weighting seine and trawl samples, all individual data were assigned equal weight in estimating first-year growth. Although the seasonal pattern of growth obtained from the combined samples may not pre-

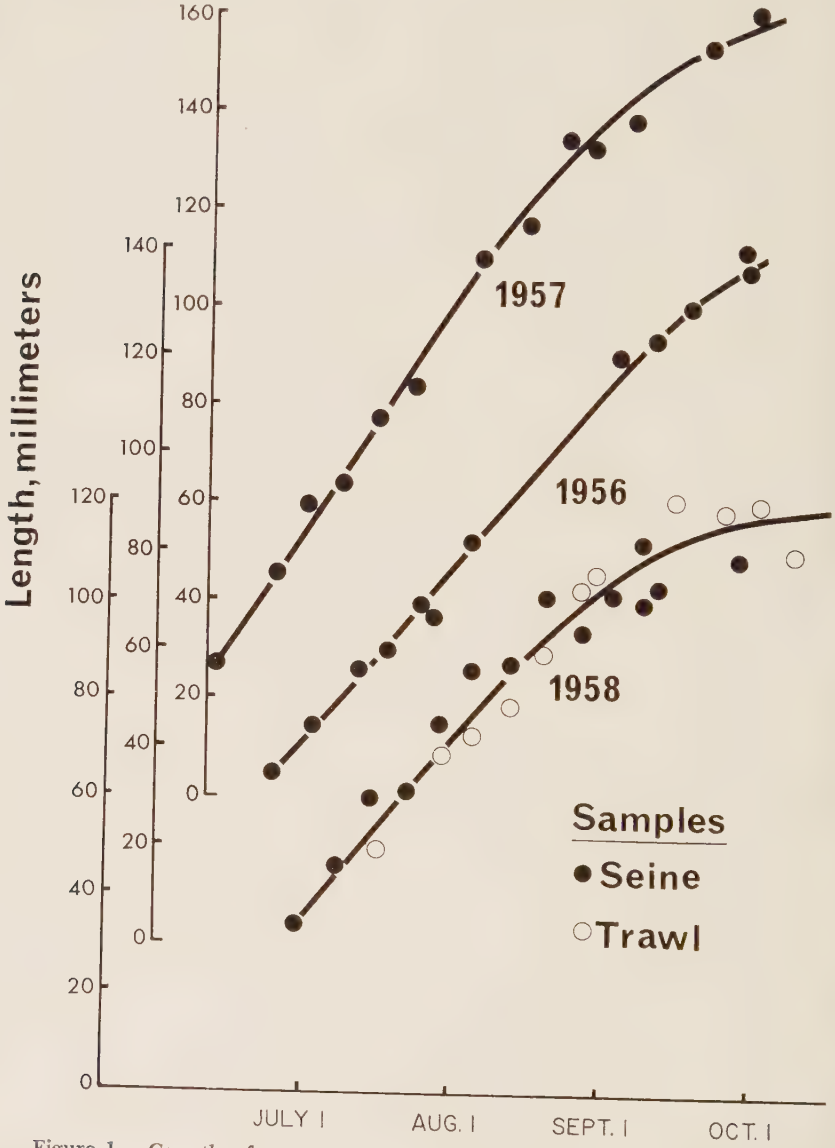


Figure 1. Growth of young-of-the-year walleyes in 1956, 1957 and 1958.

cisely represent the growth pattern of the population, length differences were sufficiently small that they could not invalidate conclusions which have been drawn from the data.

Length measurements of male and female walleyes were combined in estimating growth during the first year of life. In 24 collections of 18 to 25 fish which were sexed, females averaged longer than

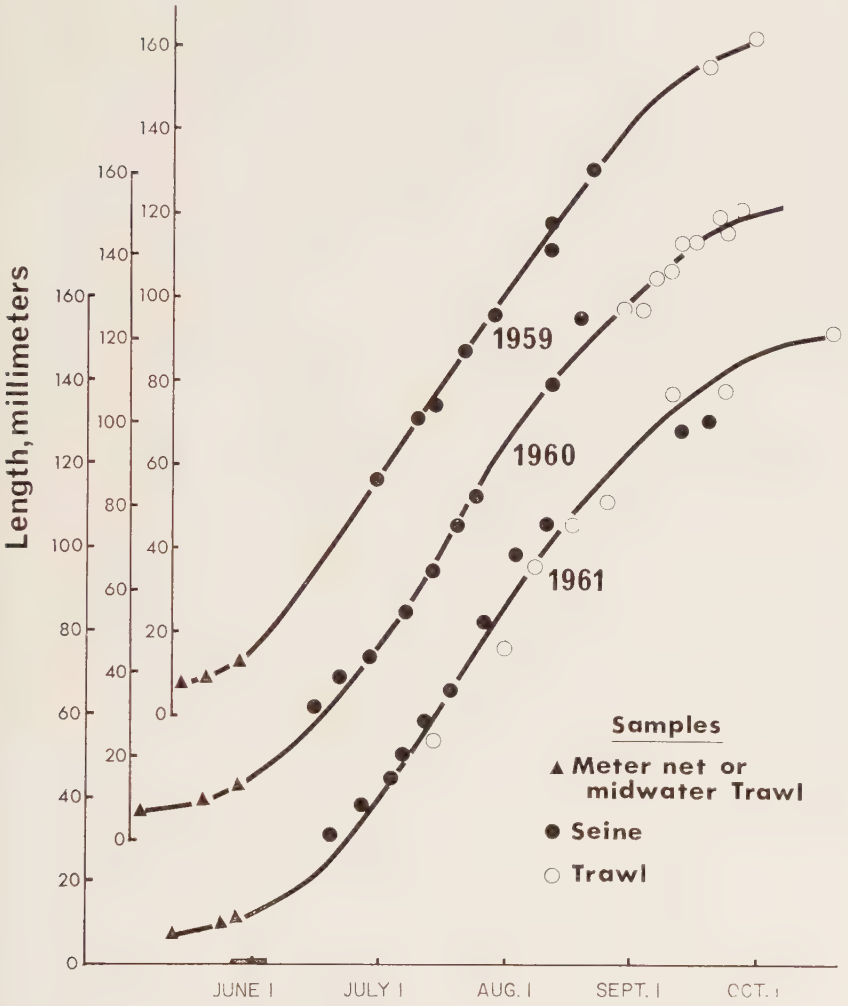


Figure 2. Growth of young-of-the-year walleyes in 1959, 1960 and 1961.

males in 13 collections and smaller than males in 11 indicating similar growth rates. The over-all sex ratio in these samples was 248 females to 243 males.

Young fish were collected at four or more locations at weekly intervals by seining or trawling, and a composite sample of 50 or more walleyes was retained for measurements. Weekly samples in 1956, 1957 and occasionally in other years consisted of fewer than 50 fish. A mean length and confidence interval was calculated for each sample. Means were plotted and smoothed curves were fitted by inspection for each year's data (Figures 1, 2 and 3) taking into account

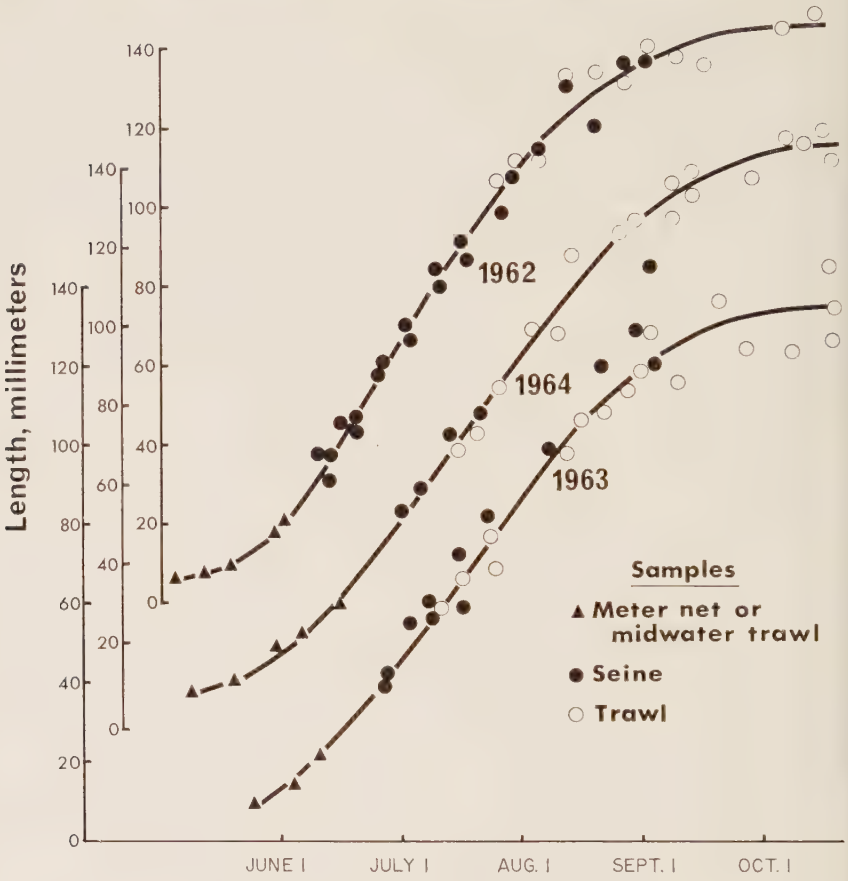


Figure 3. Growth of young-of-the-year walleyes in 1962, 1963 and 1964.

sample size and confidence limits. Lengths read from curves were used to analyze growth in different years.

Comparison of Calculated and Observed Lengths

First-year growth is frequently estimated by calculating length at the first annulus from scales of older fish using a length-scale regression. A linear length-scale regression with a length intercept of 2.28 inches was used to determine lengths of walleyes from Oneida Lake at each annulus (Forney, 1965). It was found that calculated lengths at the first annulus were consistently greater than observed lengths based on growth curves fitted to samples collected in late summer and fall (Table 1). Back-calculating to the first annulus, using only I+ fish, did not reduce the difference between calculated and observed lengths, which suggested that errors in the length-scale regression

Table 1. Comparison of Calculated and Observed Mean Total Lengths (in millimeters) for Walleyes at the End of Their First Growing Season

Year class	Calculated lengths*		Observed length§
	Number	Mean	
1956	20	150	143
1957	76	165	160
1958	21	151	119
1959	165	171	165
1960	82	171	153
1961	96	171	152
1962	62	160	145
1963	96	150	131

* At first annulus as determined from scales of age I+ fish.

§ At end of first growing season as estimated from growth curves fitted to samples of young collected in summer and fall.

Table 2. Comparison of Observed Lengths (in millimeters) in Fall and the Following Spring for the 1962, 1963 and 1964 Year Classes of Walleyes with Lengths at the First Annulus Back-calculated from Scales of Age I+ Fish

Item	Number of fish	Mean length	Standard deviation	Value of *t*
1962				
Observed length				
Fall	92	147.7	1.83	
Spring	88	158.8	2.09	4.01*
Calculated length at first annulus	62	160.0	1.89	xxx
1963				
Observed length				
Fall	94	134.7	1.91	
Spring	66	153.8	3.34	5.29*
Calculated length at first annulus	96	150.0	0.92	xxx
1964				
Observed length				
Fall	321	141.6	1.33	
Spring	166	161.8	2.28	8.18*
Calculated length at first annulus		..	.	.

*$P < .01$.

would not explain these differences in estimated lengths at the end of the first growing season.

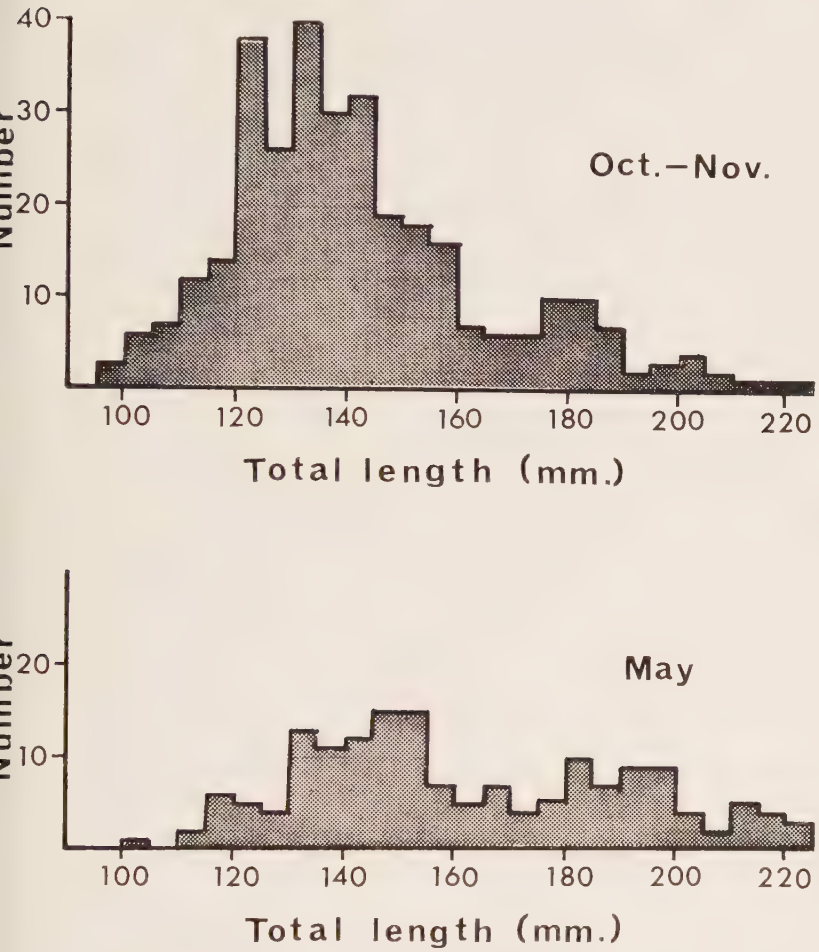
Apparent changes in mean length of the population between spring and fall were investigated by comparing observed lengths of fish taken in late fall with those of fish taken the following spring. Young walleyes were collected by trawling at 10 sites in late October and November of 1962, 1963 and 1964, and samples of these year classes were collected at the same sites by trawling during the first week in May of 1963, 1964 and 1965. In these years, observed mean lengths in late fall were significantly less than those of the ocrresponding year classes the following May (Table 2). Calculated lengths of the 1962 and 1963 year classes at the first annulus were in close agreement with observed lengths of fish of the same year classes collected in the spring (Table 2). This agreement suggests that the size distribution of walleyes taken by trawling in the spring was representative of the population, and it is reasonable to assume that samples taken in the fall with the same gear are equally reliable.

Growth of walleyes between fall and spring and size selective mortality of young over winter are two possible explanations for the increase of up to 20 millimeters in mean length between fall and the following spring. Samples of young taken in October and November suggest that very little growth occurred after October 1 in most years and that growth probably had not resumed by the first week in May since water temperatures were below 50° F. and annulus formation was not observed until late May. It seems more likely that the increase in mean length between fall and spring was caused by a high overwinter mortality among the smaller fish in the 1962 to 1964 year classes. The length distribution of the 1964 year class which was strongly skewed to the left in the fall was more nearly normal in shape by spring (Figure 4). Similar changes in length distribution were evident in comparing samples of the 1962 and 1963 year classes collected in fall and spring. Frequent occurrence of young walleyes in stomachs of older walleyes during late fall indicated considerable cannibalism, but available data were not adequate to determine if predation was size selective.

Although calculated lengths provided a reliable estimate of mean length of the population in the spring, this is not an accurate estimate of first-year growth in Oneida Lake. For this reason growth of young was based entirely on observed lengths of walleyes collected in summer and fall.

GROWTH RATE

In the years 1959 through 1964 when sampling was begun in May, rate of growth in length gradually increased until walleyes reached



igure 4. Composite length distribution for walleyes of the 1964 year class collected at 10 locations by trawling in October and November of 1964 and in early May of 1965.

length of about 20 millimeters during the first or second week in une. From mid-June to mid-August, for all years except 1962, weekly ength increments were relatively constant. Growth in 1962 was xceptionally rapid in May and June but began to decrease by mid-uly. The growth rate of most year classes declined from late August hrough September. The 1957, 1959, 1960 and 1961 year classes naintained a relatively rapid growth rate in September compared ith that of other year classes.

Very little growth occurred after October 1. Comparison of mean engths on October 1, read from the growth curves shown in Figures and 3, with those for samples of 100 or more fish taken in late

October and November of the years from 1960 to 1961 suggests that 97 to 100 per cent of a season's growth was completed by October 1.

Raney and Lachner (1942) estimated first-year growth of walleyes in Oneida Lake from seine samples collected from July through October in 1940. Their published growth curve indicates a relatively constant rate of growth from July through August and a rapid decrease during early September. The 1940 year class attained a length of about 132 millimeters on October 1, which was within the range observed during the present study.

Factors Controlling Growth

The relationship of first-year growth of walleyes to temperature, kind of food eaten, and abundance of forage fish was examined.

Temperature Estimated mean lengths of walleyes at the end of each month were read from growth curves (Figures 1, 2 and 3) and compared with air temperature indices from May 1 to the corresponding date as recorded at the U. S. Weather Bureau Station at Hancock Field located 9 miles southwest of Oneida Lake. The indices were obtained, in the usual way, as follows. Monthly temperature averages were calculated from daily means, and the values for each month were subtracted from long-term averages to obtain monthly deviations. Algebraic sums of these deviations were calculated for

Table 3. Estimated Mean Total Lengths (in millimeters) of Age 0+ Walleyes in Successive Months During the 1956 to 1964 Growing Seasons and Summation of Monthly Air Temperature Indices

Year	Period							
	May–July 1		May–August 1		May–September 1		May–October 1	
	Mean length July 1	Temp. index May–June	Mean length Aug. 1	Temp. index May–July	Mean length Sept. 1	Temp. index May–Aug.	Mean length Oct. 1	Temp. index May–Sept.
1956.	42	−5.1	76	−9.4	112	−10.5	140	−15.1
1957.	55	0.9	101	−1.2	138	−4.4	158	−5.2
1958.	36	−8.5	73	−10.5	103	−11.7	118	−13.2
1959.	58	2.1	102	3.1	143	6.9	163	10.8
1960.	48	0.9	95	−2.2	131	−3.8	152	−3.4
1961.	40	−3.5	87	−4.1	124	−4.0	147	2.1
1962.	64	5.1	108	1.8	135	0.6	143	−3.1
1963.	46	−4.2	84	−5.0	118	−9.2	130	−15.2
1964.	50	2.1	90	2.8	125	0.0	139	−1.8
Rank correlation	0.92		0.86		0.83		0.58	

the periods May-June, May-July, May-August and May-September to obtain the indices which were compared with the mean lengths of walleyes on July 1, August 1, September 1 and October 1 (Table 3). The degree of correlation between first-year growth and temperature was measured by Spearman's coefficient of rank correlation (Steel and Torrie, 1960, p. 409). Length attained by July 1 was closely correlated with the May-June temperature index (r_s=0.925, $P < 0.05$), but the correlation between the length and temperature indices decreased in successive months. The biological meaning of the significant correlation coefficients for the May-July and May-August periods is not clear. Length in late summer was influenced by length attained by July 1, and the May-August temperature index, for example, was partly determined by the May-June index. Thus a high correlation for May-June might result in significant correlations for a longer time period even if there were no relationship between growth and temperature after July 1.

Food Utilization and Growth Stomach contents of walleyes collected during July-September from 1958 to 1964 were examined to determine seasonal and annual changes in diet. Analysis of samples taken in 1963 and 1964 suggested that walleyes collected along shore by seining did not consume the same foods as those collected in deeper water by trawling (Table 4). In August and September walleyes seined near shore contained more sunfish and fewer entomostraca than those netted offshore. Combined trawl and seine samples might provide the most representative picture of food habits, but seine samples were not available in each year and estimates of growth in late summer were based largely on samples taken in trawls. For these reasons comparison of the food in different years is based entirely on walleyes taken by trawling.

Samples of 20 to 25 walleyes for stomach analysis were selected at random from the total weekly catch at four to 10 trawling sites. Total lengths of these specimens were measured, and the food items in their stomachs were noted. Results are expressed in frequency of occurrence calculated by dividing the number of fish containing a specific food item by the total number containing food. Fish in the stomachs were identified to species when possible. Chironomid larvae and pupae were the only insects observed in walleye stomachs. Entomostraca were not identified, but cursory examination of some stomachs suggested that copepods and *Leptodora* predominated. The only additional food items observed were amphipods in four stomachs and snails in two.

Pronounced changes in the incidence of fish in the diet were evident between years (Table 5). In 1959 and 1960 all walleyes examined had fed exclusively on fish from July through September. In

Table 4. Frequency of Occurrence of Food Items in Stomachs of Young Walleyes Taken in July through September of 1963 and 1964.

Year	Month	Gear	Number stomachs examined	Number containing food	Frequency of occurrence (per cent)						
					Fish					Invertebrates	
					Yellow perch	Johnny darter	Sunfish	Other	Unidentified	Chironomids	Entomostraca
1963.....	July	Seine	104	81	55.6	8.6	0	0	35.8	0	0
		Trawl	95	75	52.0	0	0	0	29.3	1.3	18.6
	August	Seine	69	38	21.0	10.5	10.5	7.9	44.7	2.6	2.6
		Trawl	90	73	31.5	8.2	1.4	2.7	32.9	1.4	23.3
	September	Seine	74	62	4.8	4.8	51.6	3.2	32.2	6.4	3.2
		Trawl	86	55	18.2	7.3	9.1	1.8	29.1	3.5	32.7
1964.....	July	Seine	107	87	18.4	11.5	0	2.3	47.1	28.7	0
		Trawl	80	50	36.0	0	0	2.0	34.0	0	0
	August	Seine	23	21	14.3	4.8	38.1	4.8	33.3	0	4.8
		Trawl	96	79	16.4	12.6	15.2	2.6	31.6	16.4	10.1
	September	Seine	50	36	5.6	22.2	11.1	0	66.7	5.5	0
		Trawl	90	78	6.4	9.0	9.0	6.4	20.5	9.0	47.4

Table 5. Frequency of Occurrence of Food Items in Stomachs of Walleyes Taken by Trawling in July through September from 1958 to 1964 and Monthly Length Increments as Read from Growth Curves

Month	Year	Number stomachs examined	Number containing food	Frequency of occurrence (per cent)								Length increment (millimeters)
				Fish*	Yellow perch	Johnny darter	Sculpin	Sunfish	Other fish	Chironomids	Entomostraca	
July	1958	49	39	97.4	38.5	0	0	0	0	0	3.6	37
	1959	50	41	100.0	42.0	0	0	0	0	0	0	44
	1960	0	0	0	0	0	0	0	0	0	0	47
	1961	89	68	100.0	45.6	0	0	0	0	0	0	47
	1962	71	49	100.0	51.0	0	0	0	0	0	0	44
	1963	95	75	81.3	52.0	0	0	0	0	1.3	18.6	38
	1964	80	50	72.0	36.0	0	2.0	0	0	12.0	18.0	40
August	1958	86	66	75.8	36.4	3.0	0	0	0	3.0	21.2	30
	1959	75	59	100.0	40.7	1.7	1.7	6.8	0	0	0	41
	1960	100	76	100.0	28.0	8.0	2.0	0	2.0	0	0	36
	1961	102	67	100.0	67.2	0	1.5	0	0	0	0	37
	1962	90	62	91.9	27.4	9.7	3.2	0	0	0	11.3	27
	1963	90	73	76.7	31.5	8.2	2.7	1.4	0	1.4	23.3	34
	1964	96	79	78.5	16.4	12.6	1.3	15.2	1.3	16.4	10.1	35
September	1958	25	18	88.9	50.0	0	0	0	0	5.6	11.1	15
	1959	64	50	100.0	30.0	14.0	0	62.0	0	0	0	20
	1960	86	59	100.0	39.0	13.6	0	0	1.7	0	0	21
	1961	81	53	92.7	43.4	3.8	1.9	3.8	0	0	7.3	23
	1962	84	55	78.2	20.0	16.4	1.8	0	3.6	1.8	25.4	8
	1963	86	55	65.4	18.2	7.3	1.8	9.1	0	3.5	32.7	12
	1964	90	78	50.0	6.4	9.0	3.8	9.0	2.6	9.0	47.4	14

* Includes unidentified fish remains.

1961 consumption of fish was high, but a few specimens collected in September had fed on chironomids and entomostraca. In 1958, 1963 and 1964 chironomids and entomostraca were observed in the stomachs during July and became increasingly important in late summer.

Monthly growth increments read from observed growth curves (Figures 1, 2 and 3) are shown in the last column of Table 5. August and September growth increments were highest in 1959, 1960 and 1961, and in these years walleyes fed almost exclusively on fish. Growth increments were lower in 1958, 1963, and 1964 when invertebrates were common in the diet. Yellow perch occurred more frequently in the diet of walleyes than any other forage fish. Since estimates of yellow perch density were available, the relation between walleye growth and the abundance of perch was examined.

Abundance and Size of Yellow Perch An index of yellow perch abundance from 1959 through 1964 was obtained by trawling at four sites on 12–24 days in August and September (48–96 hauls). Yellow perch density, as measured by the mean catch per haul, was not correlated with the length increments of walleyes between August 1 and October 1 (Table 6). Although the trawl catch suggests that

Table 6. Average Number of Yellow Perch Taken at Four Stations in August and September from 1959 to 1964 and Walleye Growth from July to October

Year	Yellow perch (catch per haul)	Walleye growth (millimeters)
1959	57	105
1960	814	104
1961	516	107
1962	1,062	79
1963	543	84
1964	1,126	89

yellow perch abundance was highest in 1964, growth of walleyes was comparatively slow and the occurrence of yellow perch in the stomachs of walleyes was lower in 1964 than in other years.

The proportion of young yellow perch in the diet generally decreased from July to September in each year and this decrease was pronounced in 1963 and 1964. Comparison of the food of young walleyes of different sizes examined in September of 1963 and 1964 (Table 7) indicates larger walleyes continued to feed on yellow perch while smaller walleyes contained mostly invertebrates in September. This suggests that by late summer young perch may grow beyond the size where they are fully vulnerable to predation by walleyes.

Table 7. Frequency of Occurrence of Food Items in Stomachs of Young Walleye Collected in September of 1963 and 1964 Summarized by Length of the Walleyes

Length (millimeters)	Number stomachs examined	Number containing food	Frequency of occurrence (per cent)							
			Fish*	Yellow perch	Johnny darter	Sculpin	Pumpkin-seed	Other fish	Chirono-mids	Entomo-straca
80–99	13	10	10.0	0	0	0	10.0	0	10.0	80.0
100–119	52	42	26.2	0	7.1	0	9.5	0	14.3	71.4
120–139	58	44	47.7	2.3	9.1	6.8	9.1	2.3	6.8	52.3
140–159	31	25	92.0	28.0	8.0	4.0	8.0	4.0	0	8.0
160–179	19	11	100.0	54.5	18.2	0	9.1	0	0	0
180–199	3	2	100.0	50.0	0	0	0	0	0	0

* Includes unidentified fish.

Table 8. Estimated Mean Lengths of Age 0+ Yellow Perch in Oneida Lake as Read from Smoothed Curves Fitted to Means of Samples Collected at Weekly Intervals from 1956 to 1964

Year	Mean length (millimeters)			
	July 1	August 1	September 1	October 1
1956	32	47	58	64
1957	33	53	60	62
1958	22	42	55	58
1959	34	53	68	77
1960	32	48	61	69
1961	26	40	51	59
1962	35	51	65	73
1963	29	47	59	61
1964	33	49	64	71

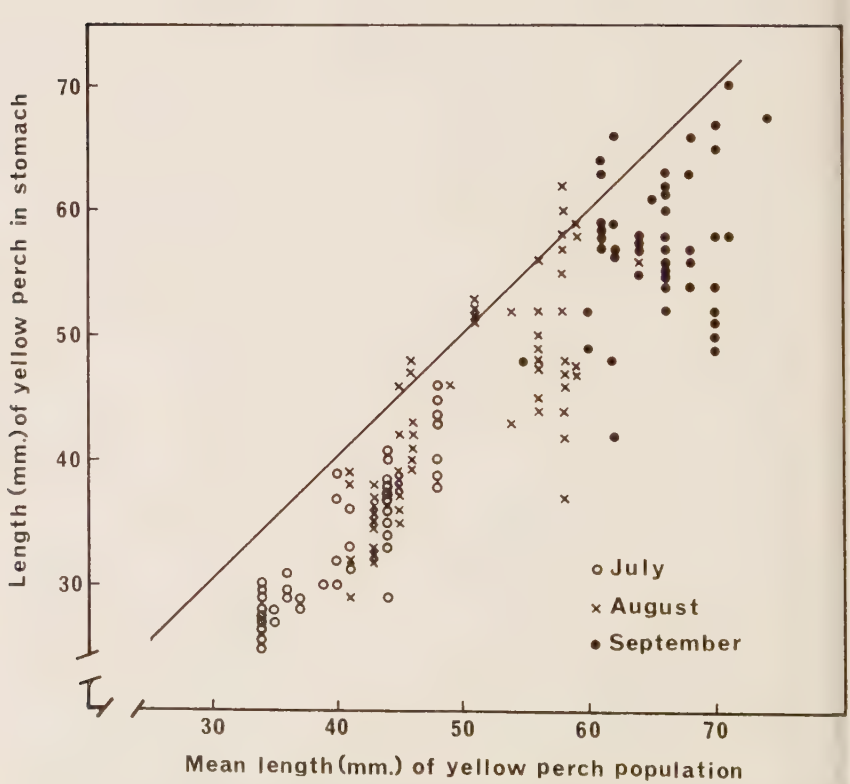


Figure 5. Distribution of length of yellow perch found in stomachs of walleyes in 1961-1964 in relation to mean length for the yellow perch population on the date of collection. Points below the 45° diagonal represent perch smaller than the population mean length.

Observed growth of yellow perch in Oneida Lake during the summers of 1956 to 1964 was determined from measurements of 50 to 100 young collected at about weekly intervals by seining and trawling. Sample means were plotted and smoothed curves drawn to describe growth in each year. Estimated mean lengths of yellow perch on July 1, August 1, September 1 and October 1 were read from growth curves and are shown in Table 8.

The lengths of yellow perch in the stomachs of walleyes examined from 1958 to 1964 were measured, when possible, and compared with the estimated mean length of perch on the day of capture as read from growth curves. Over 90 per cent of the yellow perch in the stomachs were less than the estimated population mean length (Figure 5), which suggests that only the smaller perch were available as forage. Errors in measurement of perch in the stomach caused by shrinkage or distortion were not considered serious, since the mean length of young perch from stomachs of large walleyes (12–20 inches long) was in close agreement with estimates of population mean length.

Incidence of perch in the diet of young walleyes may be determined by both density and length of perch, but in most years length was probably of greater importance. Mean lengths of perch on September 1 and the frequency of occurrence of perch in walleye stomachs examined in August and September from 1958 to 1964 (Table 9)

Table 9. Comparison of Estimated Mean Total Length of Yellow Perch on September 1, Walleye Growth from July to October, and Frequency of Occurrence of Yellow Perch in Walleye Stomachs in August and September for Years 1958 to 1964

Year	Length of yellow perch on September 1 (millimeters)	Walleye growth July 1–October 1 (millimeters)	Frequency of yellow perch in walleye stomachs in August and September* (per cent)
1958	55	82	40.5
1959	68	105	35.8
1960	61	104	38.5
1961	51	107	56.7
1962	65	79	23.9
1963	59	84	25.6
1964	64	89	11.5

* See Table 5.

showed a moderately high rank correlation of –0.54. Although this correlation was not significant ($P = 0.2$), it was substantially higher than that between the abundance of perch and their occurrence in the diet during the same period.

Length distribution and First-year Growth

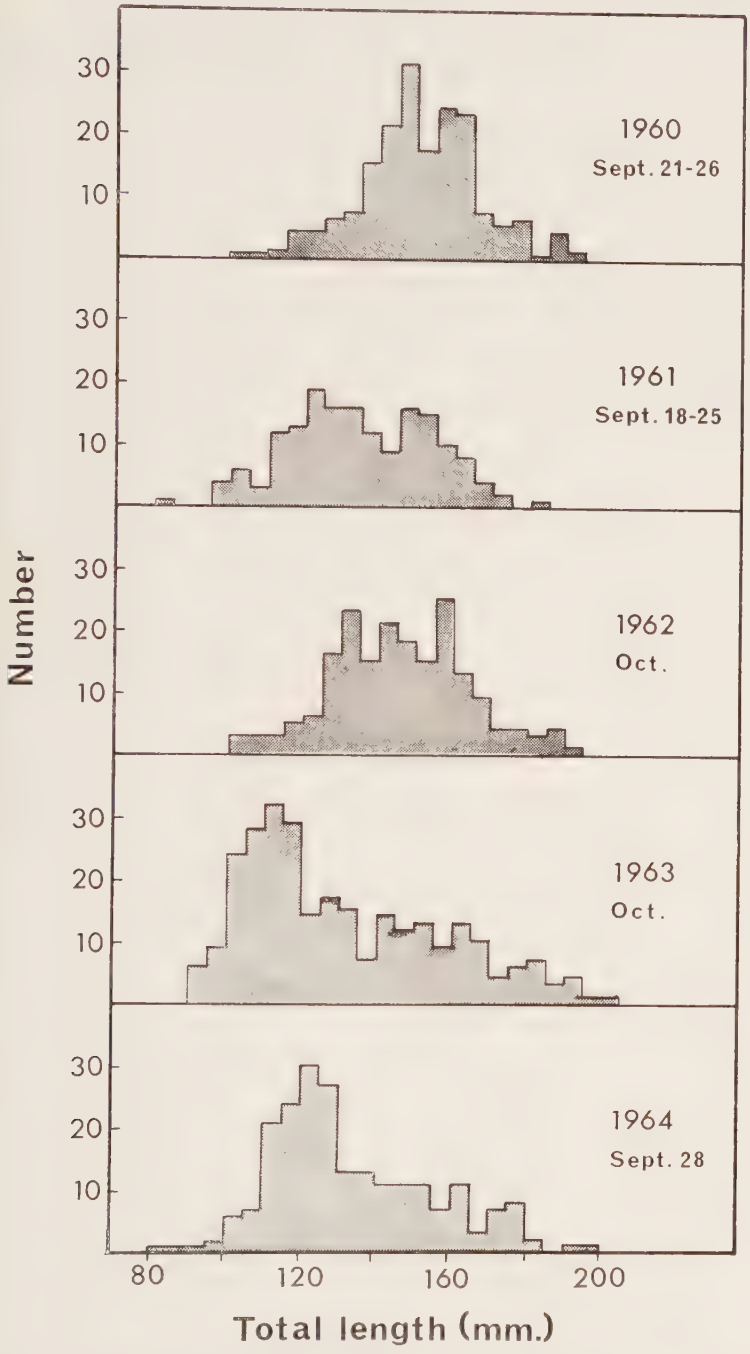
Length-frequency distributions of young walleyes collected in the fall of the years 1960 to 1964 exhibited pronounced differences in shape (Figure 6) which appeared related to annual growth and type of food consumed. The length-frequency distribution of each year class was based on samples taken at eight or more locations by trawling during a 4- to 8-day period in late September or October. Length distribution was most asymmetrical in 1963 and 1964, and growth rate, based on mean length attained by October 1, was slower in 1963 and 1964 than in other years (Table 10). Coefficients of skewness (Snedecor, 1956, p. 201) calculated for the 1963 and 1964 samples were highly significant ($t = 4.66$ and 3.46, respectively) indicating asymmetry in the samples was attributable to pronounced skewness in the length distributions of walleye populations in both years. Although the mean length of the population was lower in 1963 and 1964 than in the period 1960 to 1962, the range in length was greater and the largest individuals appeared in the 1963 and 1964 samples. The higher variance associated with samples taken in 1963 and 1964 reflects the broad range and skewness of the length distributions in both years (Table 10). In contrast the 1960 year class, which attained the greatest mean length by October 1, had the lowest sample variance of the five year classes.

Food of walleyes in August and September of 1963 and 1964 consisted of chironomid larva, zooplankton and fish, but in 1960 only fish were found in the stomachs examined. Small walleyes in the 1963 and 1964 year classes fed on invertebrates whereas the larger ones consumed fish (Table 7). Differences in food habits between large and small walleyes would broaden the length distribution of the year class and possibly lead to a skewed distribution such as observed in 1963 and 1964.

DISCUSSION

Mean lengths of the 1956 to 1964 year classes of walleyes ranged from 118 to 163 millimeters on October 1 of the first growing season. Probably the two most important factors determining differences in first-year growth were May-June air temperatures and the relative availability and density of forage fish in late summer.

Mean lengths of walleyes on July 1 ranged from a low of 36 millimeters in 1958 to 64 millimeters in 1962. The calculated rank correlation of 0.92 between annual May-June air temperatures suggests that lake temperatures determined the rate of growth in early summer. To some extent the correlation may also reflect early or late hatching of walleye fry which would have been influenced by the air temperature regime in early May.



gure 6. Length-frequency distributions of young-of-the-year walleyes collected by trawling in the late summer of 1960, 1961, 1962, 1963 and 1964.

Table 10. Statistical Characteristics of Length Distribution of Walleyes Collected by Trawling in September and October 1960 to 1964

Year	Period	Statistics of length distribution					Estimated mean length on October 1	Occurrence of food items (per cent)	
		Number of fish	Range	Mean	Variance	Coefficient of skewness		Fish	Invertebrates
1960..	September 21–26	195	112–191	149.7	273.8	−0.0447	152	100.0	0.0
1961...	September 14–18	168	81–180	133.6	364.1	−0.0664	147	92.7	7.3
1962..	October	191	102–190	144.8	322.4	0.0808	143	78.2	25.4
1963....	October	278	90–203	130.0	714.2	0.6815	130	65.4	36.2
1964..	September 14 20	219	82–198	133.2	412.9	0.5710	139	50.0	53.8

Midsummer growth of walleyes was less variable than early- or late-season growth. Length increments ranged from 37 to 47 millimeters in July and from 27 to 41 millimeters in August during the 9-year period of study, but growth increments were not closely correlated with air temperatures during these months. The lowest July-August growth increments occurred in 1958, 1963 and 1964 when invertebrates were common in the diet, and the largest increments occurred in 1959 and 1960 when walleyes consumed fish.

Evidence that the food supply limited the growth rate was most apparent in comparing growth increments with food in September. These increments were highly variable ranging from 8 to 23 millimeters, and annual differences in diet were more pronounced in September than in other months. The largest increments occurred in 1959, 1960, and 1961 when nearly all walleyes fed on fish, while lower increments were observed in years when the type of food consumed was more diverse. Ivlev (1961) has shown experimentally that fish population reared under adverse food conditions often consume a greater variety of food items than do populations with unlimited food supplies. The increased range in length and the skewed length distributions of walleye year classes in 1963 and 1964 when the growth rate was slow may reflect limited availability of forage fish in late summer. Nikol'skiĭ (1962) noted similar changes in length distribution and food habits among year classes of fish subject to food competition of varying intensity.

The effect of changes in density of forage fish on the growth rate of young walleyes was difficult to measure because the species composition of the forage population and their vulnerability to predation varied annually. Although yellow perch were generally the most abundant forage fish in Oneida Lake and were important in the diet of walleyes, indices of perch abundance were not correlated with July to October growth increments of walleyes. Probably the growth rate

Table 11. Relative Abundance of Sunfish Taken at Four Stations in August and September and Their Frequency of Occurrence in Walleye Stomachs, 1959–1964

Year	Mean catch per haul	Frequency in walleye stomachs (per cent)
1959	72.1	62.0
1960	1.6	0.0
1961	19.6	3.8
1962	3.8	0.0
1963	10.1	9.1
1964	14.9	9.0

of young perch determines the proportion of the perch population that is vulnerable to walleye predation in late summer. This would tend to obscure any direct relation between abundance of yellow perch and growth of walleyes. Also, variation in abundance of sunfish and other forage fish must be considered in interpreting the effect of perch density on walleye growth. Young pumpkinseed sunfish were exceptionally abundant in standard trawl hauls at four index stations during August and September in 1959, and they were the most important item in the diet of walleyes during September 1959 (Table 11). The high density of sunfish in 1959 may explain the rapid growth of walleyes during late summer in a year when yellow perch were scarce.

Although samples of walleyes taken in the fall indicated first-year growth was usually completed by October 1, mean lengths of most year classes increased substantially between fall and spring. Changes in population length-frequency distribution between fall and spring indicate the increase in population mean length may result from a high overwinter mortality of small walleyes. This suggests that year classes which grow rapidly during their first year should experience lower mortality over winter than slower growing year classes. The possible effect of first-year growth on survival and establishment of year class strength needs further study.

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TRENDS IN ABUNDANCE OF THE MAYFLY (*HEXAGENIA LIMBATA*) AND CHIRONOMIDS IN ONEIDA LAKE[1]

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ABSTRACT

Analysis of bottom samples collected at three stations in Oneida Lake from 1956 to 1964 showed a decrease in the abundance of the mayfly (*Hexagenia limbata*) and an increase in chironomid populations. Oxygen depletion in the hypolimnion during periods of calm weather and possibly increased eutrophication of Oneida Lake were probably responsible for these population changes.

During the summer each year from 1956 to 1964 a series of bottom samples were taken at three stations near Shackelton Point on Oneida Lake, New York (Figure 1) to obtain a rough index of the invertebrate fish food present. With so small a sample area, no comprehensive measurement of subtle fluctuations in bottom fauna was intended. But since the results agreed so well with observed trends in abundance of the mayfly (*Hexagenia limbata*) and chironomids on the entire lake, these fragmentary findings seem worthy of notice.

Oneida Lake is a eutrophic body of water located in central New York State. It is roughly rectangular and has an area of 80.4 square miles. Maximum and mean depths are 55 feet and 25 feet, respectively (Mt. Pleasant *et al.*, 1962). The relatively flat surrounding terrain, coupled with the fact that the lake's long axis lies east and west, provides the prevailing westerly winds with a fetch of nearly 19 miles. These factors cause almost continuous mixing of the lake water at all levels during the ice-free months. However, during extended periods of calm weather, stratification may occur with subsequent depletion of oxygen in the hypolimnion.

The past abundance of mayflies in Oneida Lake has been well documented (Baker, 1916, 1918a and 1918b; Adams and Hankinson, 1928). Baker (1918b) published a photograph of windrows of dead mayfly adults along the lake shore. He also recorded ". . . large areas

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[1] A contribution of Federal Aid in Fish Restoration Project F-17-R. Dr. John L. Forney, project leader, suggested the problem and gave counsel throughout the study, and both he and Dr. Dwight A. Webster, Professor of Fishery Biology at Cornell University, critically reviewed the manuscript. Dr. Henry A. Regier, Assistant Professor of Fishery Biology at Cornell University gave advice on statistical procedures. The author is indebted to all those who aided in collection and volumetric measurement of bottom samples taken. Thanks are due Carl Schofield and Edward Houde, graduate students at Cornell University, who gave advice on phases of the work.

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Figure 1. Location of the three stations in Oneida Lake where bottom samples were taken.

of the lake where the surface of the water was completely covered with dead bodies of mayflies". Residents of the Oneida Lake area have reported enormous mayfly hatches which occurred in the middle 1950's.[3] Dr. Forney stated that in June of 1957, while electrofishing for walleyes on Oneida Lake, he had to discontinue operations because the mayfly hatch was so dense that it was impossible to see the water. Conditions such as these have not been characteristic of this lake for several years.

METHODS

The sampling procedure consisted of taking two to five (generally five) Ekman dredge (6 by 6 inch) samples at each of three stations (Figure 1). An effort was made to sample each station at 2-week intervals throughout the summer, but before 1960 this procedure was not closely followed (Table 1). Bottom samples were screened and all organisms, except mollusks, were counted and preserved in 70 per cent alcohol. Volumes were determined by displacement after preservation.

The sampling stations differed considerably in depth and exposure to the lake proper. All were located by triangulation with landmarks; no effort was made to sample at precisely the same spot each time.

Station 1 was located at the western end of Delmarter Bay about one third mile from the mainland. This mud and sand-bottomed site had a depth of 14 feet and was the shallowest of the three. It was protected from the lake by Dutchman's Island which borders the northwestern side of the bay.

Station 2 was located in the lake proper about one half mile from the Shackelton Point mainland. A mud bottom, rich in black organic ooze, was found at a depth of 40 feet.

[3] John Forney, Paul Liable, and Charles Taylor, personal communications.

TABLE 1. AVERAGE VOLUME (IN MILLILITERS) OF MAYFLIES (*H. limbata*) AND CHIRONOMIDS IN EKMAN DREDGE SAMPLES TAKEN AT THREE STATIONS IN ONEIDA LAKE, 1956–64

Year	Day	Mayflies			Chironomids		
		1	2	3	1	2	3
1956	August 25	0.09	0.75	..	0.11	0.14	..
	September 19	0.07	0.47	..	0.12	0.10	..
	October 13	0.01	1.02	..	0.06	0.08	..
1957	April 25	0.02	0.29	..	0.15	0.13	..
	May 8	..	..	0.25	..	..	0.51
	June 25	0.06	0.14	0.11	0.00	0.11	0.40
	July 20	0.06	0.14	0.02	0.05	0.07	0.17
	September 3	0.06	0.06	0.23	0.10	0.09	0.06
	November 16	..	0.36	..	..	0.08	..
1958	May 7	0.05	0.07	0.20	0.05	0.05	0.05
	June 3	0.05	0.94	0.18	0.06	0.09	0.25
	July 8	0.09	2.09	0.24	0.13	0.06	0.29
	August 14	0.21	0.05	..	0.05	0.15	..
	September 11	0.00	0.06	0.06	0.20	0.13	0.60
1959	May 4	0.04	0.16	0.04	0.09	0.46	0.49
	June 20	..	0.06	..	..	0.45	..
	October 15	0.00	0.04	0.00	0.03	0.05	0.10
1960	June 8	0.02	0.09	0.05	0.07	0.26	0.33
	June 22	0.03	0.14	0.07	0.14	0.17	0.29
	July 8	0.04	0.28	0.05	0.05	0.30	0.17
	July 25	0.00	0.004	0.07	0.12	0.11	0.19
	August 5	0.00	0.004	0.00	0.09	0.14	0.20
	August 30	0.08	0.04	0.003	0.09	0.18	0.20
	September 8	0.02	0.03	0.00	0.08	0.13	0.40
	October 10	0.00	0.05	0.00	0.05	0.10	0.17
1961	June 2	0.04	0.07	0.04	0.02	0.45	0.28
	June 14	0.00	0.00	0.00	0.07	0.27	0.01
	July 21	0.00	0.01	0.00	0.22	0.23	0.19
	August 18	0.00	0.00	0.00	0.18	0.15	0.35
1962	May 9	0.00	0.00	0.00	0.05	0.47	0.67
	May 24	0.00	0.00	0.00	0.38	0.62	0.34
	June 20	0.025	..	0.05	0.11	..	0.42
	July 11	0.06	0.00	0.04	0.27	0.48	0.49
	August 20	0.02	0.06	0.02	0.58	0.62	0.84
	September 6	0.01	0.00	0.00	0.20	0.53	0.40
1963	May 20	0.00	0.00	0.00	0.06	0.48	0.20
	June 13	0.03	0.00	0.00	0.11	0.15	0.16
	June 24	0.05	0.00	0.00	0.10	0.10	0.17
	July 11	0.00	0.00	0.00	0.17	0.12	0.25
	July 25	0.00	0.02	0.00	0.08	9.12	0.10
	August 12	0.00	0.00	0.00	0.09	0.30	0.35
	August 26	0.00	0.00	0.00	0.07	0.68	0.85
	September 10	0.00	0.05	0.00	0.25	0.65	0.90
1964	June 10	0.003	0.00	0.001	0.10	0.27	0.30
	July 1	0.00	0.006	0.03	0.23	0.12	0.19
	July 16	0.00	0.00	0.03	1.00	0.51	0.31
	August 6	0.006	0.00	0.00	3.14	0.95	0.86
	August 19	0.00	0.00	0.00	2.71	0.34	0.99
	September 2	0.07	0.00	0.00	2.52	0.16	1.10

Station 3 was located in about the center of the lake 2½ miles from the nearest shore. A mud bottom at a depth of 40 feet was characteristic.

RESULTS

Mayflies, chironomids and other organisms were separated for analytical purposes. At least four genera and several species of mayflies occur in Oneida Lake (Baker, 1918b), but *Hexagenia limbata* was by far the most numerous and conspicuous species. Other species of mayfles were rarely found at the sites sampled in this study. No attempt was made to identify the various species of chironomids.

The miscellaneous group of organisms was composed primarily of isopods and oligochaetes. The volmetric values for this category were so small that they were not included in the tabular data.

Volumes of mayflies and chironomids were estimated for each sample, and those for each day at each site were averaged (Table 1). In addition the average annual volumes were computed for each sampling station (Table 2). A marked decrease in mayflies and

TABLE 2. AVERAGE ANNUAL VOLUME (IN MILLILITERS) OF MAYFLIES (*H. limbata*) AND CHIRONOMIDS AT EACH STATION

Year	Mayflies			Chironomids		
	1	2	3	1	2	3
1956	0.06	0.81	..	0.10	0.11	..
1957	0.05	0.20	0.15	0.70	0.10	0.29
1958	0.08	0.64	0.17	0.10	0.10	0.30
1959	0.02	0.09	0.02	0.06	0.32	0.30
1960	0.02	0.08	0.03	0.09	0.17	0.24
1961	0.01	0.02	0.01	0.16	0.26	0.28
1962	0.05	0.01	0.02	0.27	0.54	0.53
1963	0.01	0.01	0.00	0.12	0.33	0.37
1964	0.02	0.00	0.01	1.61	0.39	0.63

increase in chironomids occurred at each of the three sites during the 9-year period (Figure 2).

To determine if observed trends in abundance were significant, a rank correlation test was computed for mayflies and chironomids at each sampling station using the method described by Siegal (1956, pp. 202–213). The dates of sampling, as shown in Table 1, were ranked in chronological order and their respective volumes were ranked consecutively. Results of this test showed that a statistically significant decrease in the volume of *H. limbata* nymphs and a

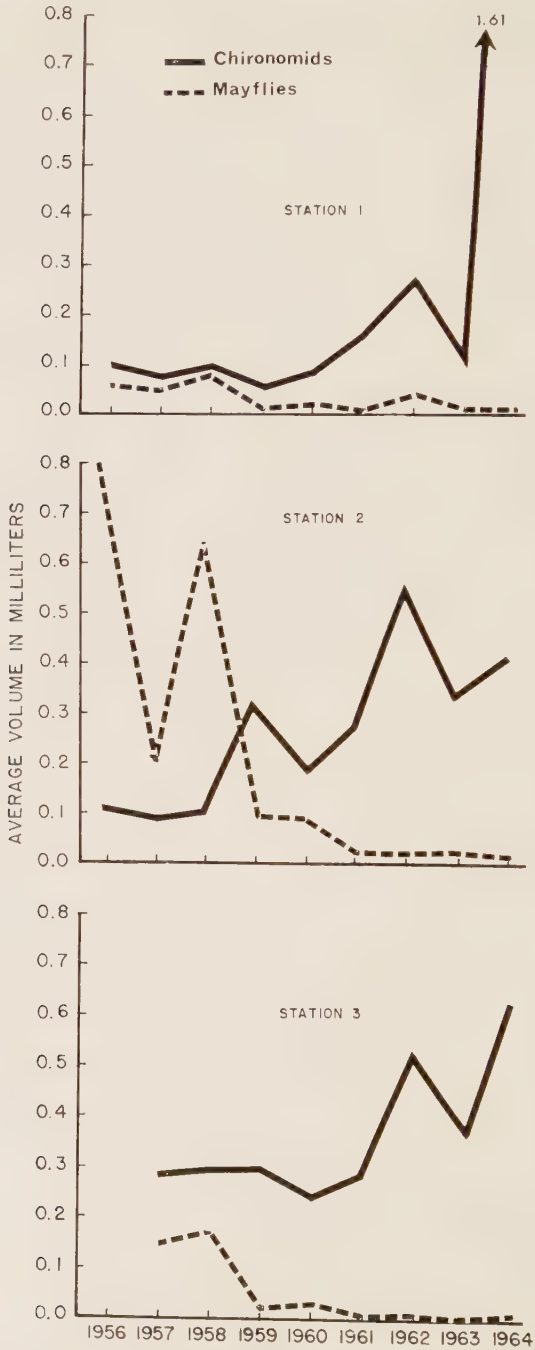

Figure 2. Mean volumes of mayflies and chironomids in Ekman dredge samples collected at each station during the summers of 1956 to 1964.

TABLE 3. RANK CORRELATION BETWEEN VOLUME AND DATE OF COLLECTION RANKED IN CHRONOLOGICAL ORDER FROM 1956 TO 1964 FOR MAYFLIES (*H. limbata*) AND CHIRONOMIDS AT EACH STATION

Station	Correlation coefficient	
	Mayflies	Chironomids
1	$r = 0.4570$ $t = 3.773^{**}$ d.f. = 44	$r = 0.4819$ $t = 3.641^{**}$ d.f. = 44
2	$r = 0.8677$ $t = 11.710^{**}$ d.f. = 45	$r = 0.5889$ $t = 4.891^{**}$ d.f. = 45
3	$r = 0.6811$ $t = 5.883^{**}$ d.f. = 40	$r = 0.3204$ $t = 2.171^{*}$ d.f. = 40

* Significant at 5 per cent level.
** Significant at 1 per cent level.

statistically significant increase in the volume of chironomid larvae occurred concurrently in the samples from each site (Table 3).

CONCLUSIONS

A similar decline in mayfly and increase in chironomid populations has been documented for Lake Erie (Britt, 1955a, 1955b, and 1963; Beeton, 1961; Carr and Hiltunen, 1963). Changes in the bottom fauna of Lake Erie have been associated with the increasingly frequent and severe oxygen depletion in the hypolimnion in recent years (Carr, 1962).

Oxygen determinations were made in Oneida Lake whenever periods of prolonged warm, calm weather or a decrease in the catch of fish from deep water suggested a temporary oxygen depletion had occurred. Low concentrations of dissolved oxygen (2.6 ppm or less) were detected in the bottom waters during 1959, 1961 and 1963. Probably the most severe oxygen deficit occurred in 1959 when the concentration at Station 2 remained below 1 ppm for 6 days and a survey indicated concentrations of less than 2 ppm in the bottom waters for over 50 per cent of the lake area during the same period. Since oxygen deficits develop rapidly following stratification and are quickly dissipated by turbulence caused by winds (Table 4), it is possible that low oxygen occurred in other years but was not detected.

The changes in bottom fauna of Oneida Lake may have resulted from repeated oxygen depletion in the deeper waters during recent years. Mayfly larvae will die within 30 to 48 hours when exposed to 1.0 ppm dissolved oxygen (Hunt, 1953). Chironomids can survive

Table 4. Oxygen and Temperature Determinations Taken in Oneida Lake at Stations 2 and 3 during a 9-day Period in 1963*

Date	Depth (feet)	Station 2		Station 3	
		Temperature (in degrees F.)	Oxygen (ppm)	Temperature (in degrees F.)	Oxygen (ppm)
July 24	5	60.5	13.0	64.5	13.6
	10	60.5	..	64.0	..
	15	60.0	10.0	62.7	10.0
	20	60.0	..	62.0	..
	25	59.0	..	62.0	10.0
	30	58.0	..	62.0	..
	35	58.0	7.0	62.0	5.2
July 29	5	82.0	11.6	81.6	13.0
	10	75.5	11.4	79.0	12.6
	20	71.2	7.2	72.0	9.2
	30	69.0	4.4	69.2	5.6
	40	67.0	3.4	69.0	3.2
July 30	5	78.5	8.6	78.0	8.8
	10	78.5	8.2	78.5	8.6
	15	78.0	8.2	78.0	8.2
	20	76.5	7.4	76.5	7.8
	25	74.5	6.8	74.5	6.8
	30	70.5	4.2	70.0	6.8
	35	70.0	2.6	69.5	4.2
	40	69.5	2.6	69.5	4.0
Aug. 1	5	74.0	6.6	74.5	7.0
	10	73.5	6.4	74.0	6.2
	20	71.0	6.4	72.0	6.4
	30	71.0	6.5	71.0	6.4
	40	71.0	7.0	71.0	7.0

* Light winds occurred from July 24 through July 29 with above normal temperature. A strong northwest wind on July 30 followed the passage of a cold front.

these conditions. Meterological factors, particularly extended periods of calm weather, may have favored unusually frequent and severe oxygen depletion in deep water during the period of study. However, it is also possible that Oneida Lake has undergone eutrophication to the point where an oxygen depletion in deep water can take place during relatively brief periods of calm weather. Beeton (1961) stated that a change in bottom fauna, from one in which mayflies predominate to one in which chironomids predominate, indicates an increase in organic matter in the sediments and thus could possibly be used as an indication of increased eutrophication.

From these data it seems evident that there has been a reduction in mayfly abundance in Oneida Lake. Furthermore, it would probably be valid to state that the niche occupied by the once abundant *H. limbata* population is being filled by various species of chironomids. Further limnological studies would be needed to determine if changes

in bottom fauna reflect an accelerated rate of eutrophication associated with rapid urbanization of the Oneida Lake watershed.

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MUSKRAT BURROWING DAMAGE AND CONTROL PROCEDURES IN NEW YORK, PENNSYLVANIA AND MARYLAND[1]

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ABSTRACT

Data on muskrat damage and control techniques were obtained through studying over 550 small impoundments in New York, Pennsylvania and Maryland. Pond leakage occurred infrequently and generally was restricted to impoundments with minimal breast widths. Impairment of physical appearance was common, especially on ponds that had narrow freeboards and shallow banks. The extent and seriousness of pond damage was highly correlated with pond age and the length of time a muskrat population had been present. Ponds built to Soil Conservation Service specifications or the equivalent seldom were severely damaged even when a population had been present for years. Burrowing activity was most pronounced in March-May following the spring movement period. Mowing of pond banks aids discovery of this activity.

Need for control and the type of control procedure to be used depends on the location and structural nature of the pond and on the size of the muskrat population. Rip-rapping, live trapping, steel trapping, multiple-catch trapping, poisoning, shooting, gassing and manipulation of water levels may be used successfully. Rip-rapping, although expensive, gave the best, relatively permanent protection. The poisoning technique developed in the study yielded the cheapest, effective control results, but it has legal limitations.

Damage caused by muskrat burrowing and den building activities has been a common concern to owners of small water impoundments for well over a decade. Complaints have been more frequent and widespread in recent years as the number of ponds and small marshes has increased rapidly. A concurrent decrease in trapping for monetary gain has aggravated the situation. The dearth of substantial information on muskrat damage and control prompted the investigations reported here. Only Nagel (1945), Beshears and Haugen (1953) and Cook (1957) were known to have conducted anything approaching comprehensive research on the subject. Mention of the problem is made more commonly in the literature, but it is of an incomplete and general nature.

Studies were undertaken in Pennsylvania in 1955–56 to determine the extent of the muskrat problem in that state. The nature of the damage, the solutions being attempted and the relative success of various control techniques were sought.

Investigations in New York from 1957 to 1959 included an intensive life history study, inquiry into damage particulars and experimentation with control approaches and techniques. Specifically,

[1] The New York portion of the study represents a contribution of Federal Aid in Fish and Wildlife Restoration Project W-77-R, although the field and pen studies carried on from 1957 to 1959 constituted part of the requirements for a Ph.D. Thesis. Special thanks are extended to W. Robert Eadie, Department of Conservation at Cornell University, who supervised this part of the work and critically read the entire manuscript. P. F. English (deceased) very ably supervised the Pennsylvania portion of the study.

answers to these questions were sought: (1) What are the most effective methods of control? (2) What are the relative merits and limitations of these control techniques? (3) When are control efforts best initiated? (4) How long must they be employed? (5) How frequently must they be repeated to insure the safety of the impoundment?

Studies in Maryland from 1962 to 1964 provided an evaluation of damage problems and control procedures on a broader regional base.

PROCEDURE

The studies differed in the three states and, therefore, the methods used are described separately.

Pennsylvania Studies

A statewide postal survey was made in 1955 to gain information on the past history and general status of the muskrat damage problem. State Soil Conservation Service and Agricultural Extension Service personnel were requested to answer several pertinent questions, documenting information given whenever possible. Identical questions were asked of both groups. Comparability of their estimations was partially achieved because each of the two reports covered the State on a regional basis.

An extensive study was made in Indiana County, selected as a representative damage area, to obtain more comprehensive data. The entire county was surveyed thoroughly and each of the 435 impoundments found was studied on the site. A critical analysis was made of the incidence, extent and nature of the damage. A detailed outline map was drawn of each pond to show all burrows, damage sites and other points of muskrat activity. In addition, the owner or another person familiar with the pond was questioned concerning the history of the structure and current damage particulars.

Authorities recognized Lancaster County as the center of the most severely damaged area of the State. An additional on-site study was made of 22 randomly selected ponds in that southeastern county to compare the problem with the one in Indiana County, a central-western county. This comparison appeared particularly useful since each of the two counties was located in the heart of one of the two apparent problem areas of the State.

Analysis of control techniques used by Pennsylvania pond owners was made largely through on-site observations and conversations and through postal questionnaire evaluations. Several types of steel traps were used by the investigator under winter conditions to evaluate trapping during the regular open season as a means of controlling muskrat populations.

New York Studies

Reproduction, growth and movement activities of muskrats in 41 small impoundments in central New York were studied from February 1957 through July 1959. Much of the resultant basic life history information was reported (Erickson, 1963). These data were examined for damage control value. Additional studies of movement, home range and homing were made, and live trapping and tagging techniques were used the year around to gather data.

Tests were conducted to develop effective methods for controlling muskrats in impoundments. Various baits were compared under pen and field conditions throughout the year. Different models and designs of steel traps, single-catch and multiple-catch live traps, aquatic traps and floating traps were tested and compared for effectiveness and practicality. Standard and original designs were used. Gassing and poisoning techniques were developed and tested.

An on-site analysis of damage in 63 central New York ponds provided a comparison with data obtained in the Pennsylvania studies. Procedures used to determine the incidence, extent and nature of the damage were similar to those used in Pennsylvania Control methods also were compared.

Maryland Studies

In Maryland 44 small water areas scattered over the State were inspected, and interviews were conducted to determine if a damage situation similar to those noted in Pennsylvania and New York existed. Control attempts were studied and compared with methods previously studied.

FINDINGS

Results of the studies are reported separately for the three states.

Pennsylvania Studies

The postal survey yielded 61 returns (100 per cent) from the Agricultural Extension Service and 36 returns (87 per cent) from the Soil Conservation Service of the State. Information reported was for the year 1954. Estimates generally were based on long familiarity with the impoundment program and firsthand knowledge of the water areas. Data complied through analysis of the estimates indicated that about 45 per cent of the approximately 9,000 ponds had a muskrat population. Nearly 65 per cent of the populated ponds were considered problematic because of damage already sustained or because of marked potential for damage existed. Of the 67 counties, 61 reported actual damage problems resulting from burrow leakage, impairment of physical appearance (destruction of banks, dike sur-

faces, etc.), roiled water, crop depredation or, more frequently, combinations of these conditions. Damage to physical appearance resulting in ragged banks, erosion and impairment of walking was by far the most prevalent problem according to the reports of cooperators. Trapping with conventional steel traps, stone and gravel rip-rapping, gassing, wire mesh rip-rapping, shooting and dogs, in that order, were used for controlling muskrats. Trapping was done almost entirely by the pond owner or his family, and poor results usually were obtained. Semiprofessional trappers seldom were involved.

In Indiana County 435 small water areas were studied on site. This was over twice the number of ponds estimated by authorities just prior to the study. The ponds averaged between ¼ and ⅓ acre, the range being from 1/10 to 35 acres. Their average age was between 3 and 4 years. When inspected, 202 were inhabited, 41 had been previously inhabited, and 192 never had had a muskrat population.

Ponds usually were invaded between early March and mid-May. Of the 202 inhabited ponds, 55 per cent were invaded within 1 year after completion, and a damage problem occurred subsequently in 58 per cent. Burrow analysis revealed an average of about 16 burrows per pond, nearly seven of which were in the breastwork. Damage to physical appearance occurred most frequently, but leakage was the most serious and costly problem. Twenty per cent of the inhabited ponds either had leaked or were leaking when the

TABLE 1. EXTENT OF MUSKRAT BURROWING CORRELATED WITH LENGTH OF TIME MUSKRATS HAD BEEN PRESENT FOR 202 PONDS IN INDIANA COUNTY (PA.) IN 1955

	Years muskrats had been present						
	1	2	3	4	5	6	Over 6
Average number per pond							
Breast burrows	3.2	7.1	7.0	7.8	8.6	9.6	4.1*
Other burrows	6.1	8.0	10.0	11.7	13.3	9.4	11.7
Total burrows	9.3	15.1	17.0	19.5	21.9	19.0	15.8*
"Dig-ups"	1.8	3.4	3.9	4.1	10.1	5.8	2.6
"Escape holes"	0.3	0.5	0.7	0.7	1.6	0.8	2.2
"Cave-ins"	2.7	4.6	3.7	6.0	5.0	5.4	9.7
Average penetration of "dig-ups" (feet)	3.1	5.3	6.6	5.7	6.1	7.4	8.2
Percentage of total burrows that leaked	1.0	1.6	1.1	2.8	0.5	4.7	3.1
Number of ponds having muskrats	41	55	49	29	10	10	8

* Two pond owners filled in "some" old breast burrows, thus lowering these values

inspection was made. Table 1 correlates burrowing activity with the length of time a population was present.

Crop damage by muskrats was seldom encountered and rarely of economic significance. Sweet corn leaves were occasionally used for lining the den. This resulted in corn being the most common subject of crop damage complaints. Roiled water conditions directly attributable to muskrat activity were of concern to a few pond owners for various reasons.

Control methods used in Indiana County are summarized in Table 2. Steel trapping was employed most frequently, but was

Table 2. Muskrat Control Methods Used in 191 Ponds in Indiana County (Pa.)

Method	Number of ponds
Trapping	82
Shooting	5
Gassing	1
Dogs	2
Partial rip-rapping	6
Trapping and shooting	13
Trapping, shooting and dogs	2
Trapping, shooting and poisoning	1
Trapping, shooting and gassing	1
Partial rip-rapping and shooting	2
Gassing and shooting	4
No control	72

usually ineffective because of poor technique. Rip-rapping was the most satisfactory method used.

An effort was made to determine why 41 ponds had been deserted by muskrats. It was felt that the answer might offer insight into effective control procedures. Trampling of pond banks by farm stock resulting in burrow destruction and fluctuations of over 2 feet in water levels accounted for most desertions. Maintenance of water levels at near flood stage, heavy trapping and intensive shooting resulted in a few.

When inspected, 192 ponds had no resident population and none had ever been present according to the owners. In all but six instances, a factor, condition or combination of factors and conditions was recognized that appeared pertinent to the absence of muskrats (Table 3).

Investigation of 22 ponds in Lancaster County, 18 selected at random and four chosen because they were undergoing extensive control procedures, indicated a damage problem similar to the one in Indiana County. A slightly higher incidence and extent of burrowing damage was noted, but this observation may lack significance in view

TABLE 3. POSSIBLE REASONS FOR ABSENCE OF MUSKRATS IN 192 PONDS IN INDIANA COUNTY, (PA.) *

Age of pond (years)	Pond age	Pond age and trampling	Pond age and water level fluctuation	Pond age and location§	Trampling	Trampling and water level fluctuation	Water level fluctuation	Location and either trampling or water level fluctuation	Location§	Rip-rap and shale or sandy banks	High water	Polluted water	Unknown
Under 1	27	2	1	1	0	0	0	0	0	0	0	0	0
1	28	4	4	2	0	1	3	0	0	0	0	0	0
2	12	2	2	0	8	2	6	2	2	1	0	0	0
3	0	0	0	0	10	1	10	1	6	1	1	2	5
4	0	0	0	0	7	0	6	0	4	1	0	0	0
5	0	0	0	0	5	2	2	1	4	0	0	0	1
6	0	0	0	0	3	0	0	0	1	0	0	0	0
7	0	0	0	0	1	0	0	0	0	0	0	0	0
8	0	0	0	0	1	0	1	0	1	0	0	0	0
9	0	0	0	0	1	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
Over 10	0	0	0	0	0	0	0	0	0	1	0	1	0
Total	67	8	7	3	36	6	28	4	18	4	1	4	6

* Figures represent number of ponds.
§ Top of hill.

of the small size of the sample (22 of some 800 ponds). Rip-rapping was used more commonly and very successfully. Heavy gravel was considered superior to wire because the latter eventually rusted. Proportionately more owners had attempted population control, and a greater variety of control methods had been tried than in Indiana County.

NEW YORK STUDIES

Life history studies of muskrats inhabiting small water areas in central New York yielded several findings that have application to damage and its control. Approximately 6.3 young were produced per litter, and about 1.5 litters were borne per female per year during the 3-year study period. The major peak in litter production occurred in the last two weeks in May. Movements between ponds took place in spring, summer and fall, but were more frequent and of longer distance in spring. Experimental data obtained by releasing 19 muskrats at various distances from their home pond indicated a strong tendency to "home".

Apples, carrots, cabbage, potatoes, sweet potatoes and commercial lures of several types were tested as baits in field and pen trails. Carrots and apples were highly superior to the others in general

acceptability. Carrots had superior durability and were slightly more effective, especially in warm weather.

Control by live trapping Havahart and National cage-type traps and Gibbs basket-type traps were tested using several settings under various conditions. Each of these single-catch models was used with some success, but the National model (6 x 6 x 24 inches, collapsible and having double-spring doors) was superior with regard to freedom from malfunction, trap-site flexibility, safety of the captive and handling ease. Tests comparing the productivity of different trap sites revealed that carrot-baited, on-shore locations were most effective, particularly when the set was made near recent muskrat sign. Observations indicated that initial trapshyness usually was overcome within 1 or 2 minutes. Shallow-water burrow sets, floating-platform sets and sets made at sign some distance from the shoreline were productive but at much lower efficiencies. The National trap with the powerful spring doors functioned smoothly under water, but only moderate success was achieved with this type of set. Muskrats were observed avoiding or circumventing the trap under these conditions. Floating-platform sets were not frequented as had been anticipated. Only moderate success was obtained because of an apparent reluctance of the muskrats to climb onto the platform and enter the trap. Captures were made at sets located away from the shoreline, but nearly a third of the animals taken were of other species.

Two multiple-catch traps were designed, constructed, tested, modified and retested. One, a push-door type, was a 3 x 5-foot cage made of poultry netting with an entrance at either end. A lightweight hardware-cloth door was suspended at an angle slanting into the trap. A V-shaped lead-in, constructed of two 12-inch strips of poultry netting 12 feet long and held in place by stakes, helped guide muskrats into the entrance area which was baited heavily with carrots. The trap was placed so as to be half on dry land and half in shallow water. The other multiple-catch device was similar but the entrances were large tapering funnels. It was tested submerged at the bottom, partially submerged in shallow water and as a surface-floating submerged set. Multiple-catch traps were tested in ponds of various sizes containing from small to large populations. As many as nine muskrats were taken at one set location, but, if the trap was not moved to a different site after 4 or 5 days, rarely were any of the remaining muskrats caught. Territorial behavior appeared to be involved (Erickson, 1963). Both designs gave best results when they were only partly submerged. Cumbersome size and exacting requirements for set location were disadvantages of the technique.

Control by steel trapping Seven steel-trap models of "killer", "stop-loss" and conventional design were tested at different trap sites

under both summer and winter conditions. Unbaited sets made with No. 1½ "killer" models in shallow water at entrances to active burrows gave best results. Little skill was required. Under icy conditions, shallow hole sets using apple-baited, stake-mounted "killer" traps worked best. Sets made on land were less productive, and additional care was required. Floating-platform sets were ineffective.

An experiment using four pond owners as cooperators compared the two most promising trapping devices, the "killer" steel trap and the National live trap. Each cooperator had had little or no experience with control procedures and owned an impoundment that supported a muskrat population. The cooperators were given equal numbers of each of the two trap types. They agreed to follow specific instructions in recording the number of muskrats caught, the type of trap in which each was taken and the weather conditions that prevailed during the trap night. Upon completion of the control effort, a trapping check was made to evaluate the cooperator's use of the prescribed techniques. Comparison of the records showed that both traps were effective as used. Within a 2-week period after control procedures were started, each man had successfully removed the population of from five to nine muskrats. Setting the steel traps was more difficult and malfunctions occurred more frequently according to the cooperators. Two-thirds of the catch was taken with the cage-type traps. Success with different set locations closely paralled results obtained elsewhere by the author.

CONTROL BY GASSING A technique using gas cartridges that are employed commonly to kill woodchucks or flush them from their burrows gave good test results. Cartridges pushed well into burrows ignited and forced muskrats to flee into traps set at openings. When all exits were sealed, lethal gas concentration resulted. Sublethal results were obtained occasionally and may have resulted from partial wetting and incomplete burning of the cartridge.

CONTROL BY POISONING In pen tests, Warfarin dusted lightly over ¼-inch-thick cross-sectional slices of carrot was more effective than equal amounts of the poison mixed into cereal and cracker preparations. Four or five poison-treated slices had to be consumed at least twice within 4 days to result in death. Field tests with two populations of tagged muskrats gave fair results. On one pond, 2½ weeks were needed to remove seven muskrats. One muskrat was trapped following the trial period. It took approximately 2 weeks to remove the entire population of six from the other pond.

"Zinc phosphide rodenticide" (U. S. Fish and Wildlife Service) with carrot as the carrier gave excellent, speedy results in pen and field tests. Cereal and cracker preparations of the rodenticide were less acceptable as bait. A concentration of 1 level teaspoon to 1 quart of

carrot slices was effective. The poison was dusted onto carrot slices placed within a quart jar. The jar then was shaken until a uniform gray coating was obtained. Consumption of four to six pieces of treated bait was lethal under penned conditions. Death followed usually in 8 to 12 hours. Immature animals were killed with lower doses. Males and females reacted similarly. Bait treated with 2 level teaspoons of poison was equally acceptable, and one or two pieces brought death in 4 or 5 hours. Eradication of seven and 10 muskrats, respectively, from two experimental ponds within 8 days represented complete kills. Both dosage levels were tested, but no difference in the speed of removal was noted. At the lower level, six pieces of poisoned bait were placed at each station. At the higher dosage, three were used. Zinc phosphide-poisoned baits have been used with some success in controlling muskrat populations in the U.S.S.R. (Azar'yan, 1961).

Additional, less intensive experiments tested rodenticide-treated bait placed in National live traps. By this means, good evaluation of the technique was obtained for several ponds. The procedure also allowed for a partial analysis of the specificity of the control method. Seasonal changes of diet had no apparent effect on the lethal dosage requirement. The baits attracted few other animals. Birds were attracted occasionally to the bright-colored, untreated carrot discs, but they were not attracted to the dull-gray, treated slices. Similarly, rabbits and, to a lesser extent, Norway rats were taken in untreated, carrot-baited live traps, but none was taken in rodenticide-treated sets.

Maryland Studies

Maryland ponds had been subjected to muskrat burrowing damage similar to that seen in Indiana County (Pa.) ponds. Physical appearance problems were common. Leakage was directly attributable to burrowing activities in three of the 44 ponds inspected. Pond construction followed basically the same pattern noted in Pennsylvania and New York. Leakage was restricted to impoundments with minimal breast widths. Control efforts included live trapping, steel trapping, shooting, gassing and poisoning. Detailed analysis of Maryland data is excluded because of the small size of the sample.

DISCUSSION AND CONCLUSIONS

Muskrat burrowing activities cause damage in many small impoundments in Pennsylvania, New York and Maryland. The extent and seriousness of the problem is strongly correlated with pond age and more specifically with the length of time muskrats have been present. Leakage is the more serious type of damage but impairment of the physical appearance is much more widespread.

Artificial impoundments built to minimum specifications of the Soil Conservation Service seldom have leakage and are less susceptible to impaired physical appearance than are ponds built with narrow freeboards and shallow banks. It would appear prudent for new ponds to be constructed on the assumption that muskrats will invade them and subject the impoundment to burrowing activity. Therefore, Soil Conservation Service specifications should be followed. If a location near an existing muskrat population is selected, additional freeboard width should be provided in the dike.

Damage potential depends not only upon the structural nature of the impoundment, but also upon maintenance aspects. Ponds that have steep banks with good cover are used heavily (Erickson, 1956). Thick vegetation in and around the pond not only provides food and cover but also inhibits early detection of damage. Marked fluctuations in water level in some instances may cause the muskrats to leave (Wilson, 1955), but they also may result in severe damage as muskrats attempt to retain water in burrow entrances yet maintain a dry den area. Rising levels are particularly conducive to digups and leakage. The latter may result as burrowing activity penetrates deeper into the dike over a period of days, weeks or even years. Proper spillway and trickle-tube design will minimize this problem.

Periodic movements of muskrats result in the establishment or reestablishment of populations in small impoundments (Erickson, 1963). The most active period of movement by far occurs in early spring and is most obvious in those years in which a pronounced thaw and rainy period occurs. Males are more active and tend to move farther, but females also are active. One year olds move more frequently than older animals. Movement generally is a random, wandering activity. Spring movements are strongly correlated with the onset of the breeding season. Most involve only a few hundred yards, but some in excess of 2 miles were noted in the live-trapping and tagging portion of this study. Summer movements are infrequent and entail very short distances. Fall ones are usually intermediate between those of spring and summer with regard to frequency and distance covered. Both summer and fall movements are most noticable when exceptionally warm, wet weather conditions exist.

Newly constructed ponds may be populated within a year, but usually 2 or 3 years pass before emigrants find conditions suitable. Sign left by transients supports this conclusion. Once established, populations grow steadily and usually peak in 5 or 6 years. Females may have two litters, each averaging about six young. Egress occurs periodically as does ingress, but it is more evident as the population increases. Desertion of ponds occurs rarely. It nearly always is brought about by overt fluctuation in water levels or by leakage which drains or nearly drains the impoundment.

Muskrat burrowing damage often is insidious. For this reason, ponds should be inspected regularly even if a population is not present. The most critical period is March-May. Movements peak in these months. Marked burrowing activity usually follows spring movements. Regular mowing of pond banks will aid in detecting damage. It has little or no influence on movements.

The need for control, the type of procedure required and the frequency of control efforts vary according to the location and structural nature of the pond and ultimately depend on the size of the population. One individual is potentially a threat to a dam with a narrow freeboard, whereas a dam with wide freeboard may support a large population and never leak. Impoundments near resident populations of muskrats may be invaded frequently and require control procedures quite different from those needed on relatively isolated ones.

Rip-rapping banks with gravel or crushed rock of approximately 1- or 1½-inch diameter affords excellent, relatively permanent protection against burrowing damage. The technique requires a complete covering of bank surfaces with a 3-inch layer of the impervious material to a minimum depth of 3 feet below and 1 foot above the normal water level. Additional coverage is required if marked fluctuation in water level is involved. This control method requires little effort beyond the original construction, but it may involve significant initial expense in materials and labor. Protection from wave erosion and enhancement of swimming and wading are considered related advantages. Rip-rapping is recommended particularly for impoundments with narrow freeboard, and those that are located near large muskrat populations. Welded wire and heavy-gauge poultry netting are usable as rip-rap but lack durability. Vertical barriers installed in dikes afford protection against pond leakage (Cook, 1957), but they do not protect the physical appearance as does rip-rapping.

Effective control may be achieved by steel trapping, live trapping, gassing, poisoning, shooting or manipulating water levels. These must usually be repeated periodicly because of seasonal movements of the muskrats. The poisoning procedure using zinc phosphide rodenticide yields very effective, inexpensive control. It can be used efficiently and safely by a novice, but it has legal limitations. A disadvantage is that the pelt is often worthless if it is recovered. Live trapping with single-catch cage traps of design similar to the National Trap Company model requires the use of the simple setting and baiting procedures described under a foregoing topic. Good control by the unskilled is likely, but much more time is required. Traps may be purchased for about $8.00 each and will last indefinitely if they are given proper care. Loss of pelt value may be avoided with this

method. Steel trapping requires much more skill than live trapping to achieve similar effectiveness. Most pond owners lack the skill and patience needed for success. Pelt value may be retained. "Killer"-type steel traps may be obtained for about a third the cost of the live trap.

Gassing with cartridges often is a laborious task. It can give excellent results, but it requires very thorough detection and treatment of all burrows. Proper placement of the cartridge without wetting demands great care. If burrows are undetected or poorly sealed, a segment of the population may escape. The entire procedure must then be repeated. Little expense is involved, but labor requirements are significant. Pelts, if recovered, usually are worthless.

Shooting is an impractical method of control for most pond owners. Few persons have the time and fewer still the skill required to take even a significant fraction of a pond population. Nonetheless, a good marksman can effect good control if he spends enough time at it.

Attempts to control populations by causing marked fluctuations in water levels may be successful (Wilson, 1955), but damage risks are high. In addition, excessively low or high water levels increase the likelihood of bank erosion.

Successful control of muskrat populations is possible through any of the controls discussed or through the use of a combination of these methods. The best approach will vary markedly in different situations depending on the structural nature of the impoundment, previous damage, population size, location, legal implications and the financial resources of the pond owner.

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OBSERVATIONS ON THE ALEWIFE (*ALOSA PSEUDOHARENGUS*) IN CAYUGA LAKE[1]

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ABSTRACT

Observations on the seasonal movements, reproduction, phototaxis, and mass mortalities of the alewife were made at Cayuga Lake, New York, during 1960 and 1961. In Cayuga Lake the alewife winters in deep water and moves into the littoral area in the spring. This movement is accompanied by the onset of courtship behavior and then spawning. These reproductive activities are discussed. Fecundity estimates are given and hermaphroditism is mentioned. Positive phototactic responses of the alewife were noted except during the spawning period. The evidence on causes of mass mortalities in the alewife was reviewed, and it was concluded that variables other than temperature are involved.

The alewife (*Alosa pseudoharengus*) is one of the several species of anadromus fishes that have developed strictly fresh-water populations. One of these populations, in Cayuga Lake, New York, (Figure 1) was studied during 1960 and 1961. As a part of these studies the scale method was evaluated for determining the age of the alewife (Rothschild, 1963) and aspects of alewife population dynamics were considered (Rothschild, 1965). In addition observations were made on seasonal movements, reproduction, phototaxis and mass mortalities. These are reported here.

SEASONAL MOVEMENTS

The alewife winters in deep water (Breder and Nigrelli, 1936; Galligan, 1951; Gross, 1959). In the spring, when the water temperature approaches 50° F., alewives begin to move into the littoral area where courtship behavior becomes evident. Cessation of courtship in midsummer is accompanied by movements into deeper water. In Cayuga Lake the alewife moves into the littoral areas in late May and early June.

In 1960 alewives were first noticed on May 15 in the mouth of Interlaken Beach Stream. They may have been attracted by warm stream water (57° F.) flowing into the cooler lake (48° F.) (cf. Collins, 1952). Shore seining near the stream and at Taughannock Point yielded no alewives. By May 27 alewives were evident in nearly every stream mouth along the eastern shore of the lake. The lake

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emperature was 51° F. and stream temperatures ranged from 59° o 62° F. Seine hauls along beaches still did not yield alewives except n the immediate vicinity of stream mouths.

On the night of June 7, 1960, the Taughannock Point area was urveyed with a 10-ampere AC shocker from 9 p.m. to 1 a.m. The ake was 57° F. and Taughannock Creek was 62° F. Small alewife chools, about 10 to 15 feet in maximum dimension, were common

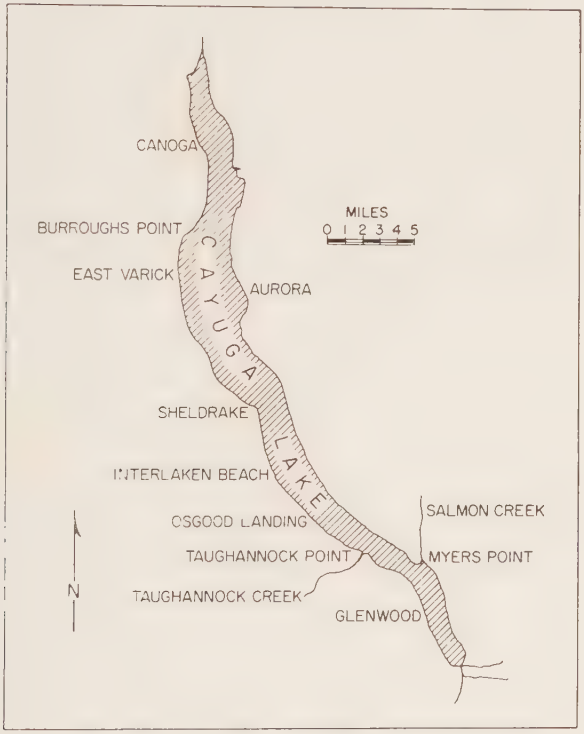

Figure 1. Map of Cayuga Lake.

n the lake. The main concentration was found in the warmer creek vater from the stream mouth upstream to the first riffle area; the den- ty of alewives in the stream was so great that distinct schools were ot discerned. By June 11, the water had warmed to 64° F. and ale- ives were common nearly everywhere in shallow water.

At Canoga Island, which was not surveyed until midsummer in 960, alewives were first evident in 1961 on May 12 when the water emperature was 52° F. and one specimen was taken. A few alewives ere taken there on each of several subsequent nights (temperature 2°–56° F.) until the first week of June. Simultaneous seining at Taughannock Point yielded no alewives. By June 5 the water tem-

perature had risen to 58° F. at Taughannock and several alewives were taken.

Alewives first appeared at Interlaken Beach Stream on June 3 in 1961 compared with May 15 in 1960. On June 3, 1961 the water temperatures of the stream and the lake were 59° F. and 50° F., respectively, and were approximately the same as the corresponding temperatures in 1960 when alewives first appeared in the stream. By June 12 the water temperature had risen to 69° F. at Canoga and 57° F. at Taughannock, and alewives were abundant at both locations. They became abundant on approximately the same date in both years.

Gross (1959) noted that alewives first appeared in the surface waters of Lake Hopatcong, New Jersey, in late April when the water temperature was 54° F. The first appearance of the alewife in Cayuga Lake was temporally later but at roughly the same temperature as Lake Hopatcong.

The increased apparent abundance of alewives in Cayuga Lake after the middle of June was accompanied by the onset of courtship and spawning activity. Alewives were generally abundant in the littoral areas until the first week in August. In early August they could only be taken in greatly diminished numbers in the littoral areas in the vicinity of Canoga and Taughannock Point. An offshore move-

Table 1. Depths at Which Major Concentrations of Alewives Were Encountered in Gill-netting Operations from June to November in Cayuga Lake*

Month	Depth in feet
June	20–70
July	20 60
August	40–200
September	40–180 and 40–120
October	50 260
November	160–230

* After Galligan (1951).

ment at this time may have been associated with completion of spawning or have been a reaction to warm surface water. Galligan (1951) presented data obtained through the operation of bottom-set gill nets which demonstrate that alewives in Cayuga Lake are found in deeper water as the seasons progress (Table 1).

REPRODUCTION

Odell (1934b) reported spawning in the Finger Lakes from late May to mid-August. Spawning generally occurred in late May or

early June (but, in one year, from July 9 to August 9) in Lake Ontario (Pritchard, 1929) and in late June in Lake Hopatcong, New Jersey (Gross, 1959). A marine population ascended a study stream in Maine from mid-May to mid-June (Havey, 1961). Gross indicated a water temperature of from 63° to 66° F. during initial spawning, and Havey's study showed that spawning runs occurred at from 50° to 60° F. Greeley (1938) observed alewives spawning at Lanoka Lake, New York, on July 15 when the water temperature was 73° F.

Courtship Behavior

Entrance of alewives into the shallow water of Cayuga Lake was coupled with the onset of courtship behavior. Fish in the stream mouths were generally oriented in an upstream direction. A single fish would leave the oriented pattern and pursue another fish. Pursuits usually terminated without the pursuing fish approaching the pursued fish. Pursuits increased in frequency with time and warmer water. Several fish would appear to pursue a single individual. At times these fish would swim in a circular pattern, splash at the surface, and then disperse.

On occasion the pursued fish would not actively swim away, but would momentarily stop; at this time the pursuing fish would be side by side with or at a slight angle to the body of the pursued fish with its head at the level of the pursued fish's dorsal fin. All in the same instant the opercula of the pursued fish would appear to flare, and the pair would swim in a rapid helical or corkscrew pattern to the surface. At the surface the two fish would break the surface of the water with at least one on its side.

This so-called swirling behavior was infrequent when the fish first moved into shallow water but increased in frequency with time and warmer water. Early season "swirls" in water as shallow as 6 inches usually consisted of two fish, but as time progressed a swirl might consist of a group of several fish. When the surface temperature approached 70° F. alewives in Cayuga Lake moved out of the shallow water into deeper water. On the evening of July 5, 1961 the surface temperature was 68° F. at Taughannock Point. Alewives were at a depth where they could not be observed except when frequent "swirls" of large numbers of alewives would literally boil to the surface and immediately descend (perhaps a reaction to the warm surface water). There were perhaps a few hundred fish in each swirl. After August 3 in 1961 spawning behavior was no longer observed, but alewife eggs were collected in a plankton net set in 20 feet of water off Taughannock Point until August 7.

Gonad Development

Pritchard (1929) and Graham (1956) observed that in Lake

Ontario male alewives matured at 3 years and females at 2 years of age. Gross (1959) suggested that alewives in Lake Hopatcong spawn only once.

Observations in Cayuga Lake indicated that males and females both matured at 2 years of age. There may be a difference in age at maturity, but this difference was not indicated in the samples. Since alewives of various ages were sexually mature in Cayuga Lake, it is presumed that they spawned more than once.

All male alewives of spawning age that entered the littoral area in the spring were in an advanced state of maturity. Testes were at a maximum size and milt was expressible from seminal tubules. Ovaries from 110 alewives were examined. Ovarian maturity increased with time. The first few females to enter the littoral area had cylindrical, elongate ovaries which contained many undeveloped ova.

The first large inshore movement of alewives consisted mostly of males. The few females contained ovaries which were nearly one-third as deep as they were long; the eggs were mostly immature. There were relatively few mature eggs in the posterior portion of the ovary. By late July and early August, females had increased in relative abundance and their ovaries were in an advanced state of maturity, being about one-third as deep as long and containing mature eggs which were mostly free of stroma. By the second week of August, the ovaries were spent and spawning was complete.

In a quiescent state the ovaries represented less than 1 per cent of the body weight. At maximum maturity in late July, the ovaries comprised about 4 or 5 per cent of the total body weight. When spawning was complete the whole visceral mass in both sexes became embedded in fatty tissue which presumably remained until gonadal activity the following spring.

Fecundity was measured by direct enumeration of mature eggs for six fish. The total length of each in millimeters together with its fecundity (in parentheses) were: 116 (8,180), 124 (7,771), 118 (9,040), 130 (5,796), 129 (7,581) and 124 10,011). Odell (1934b) gave the fecundity of 145-millimeter females (standard length) as 10,000 to 12,000 eggs.

Some male gonads were abnormal with one testis either atrophied, undeveloped or missing. There were four hermaphroditic examples in the 444 gonads examined. One hermaphroditic fish had ovarian material anteriorly and testicular material posteriorly. Fowler (1912) described a similar hermaphroditic American shad (*Alosa sapidissima*) from the Delaware River. Other hermaphrodites contained what appeared as male gonads on the right or left side and female gonads on the opposite side. Histologic examination of testicular material indicated the presence of sperm cells.

REACTION TO LIGHT

While in shallow water (during June and July), alewives exhibited no observable tactic response to light. Positive phototactic responses were evident as soon as movement to deeper water began. Kasahara (1961:122) reported that many fishes have a reduced phototactic response during spawning.

When the water surface was illuminated, alewives would aggregate immediately or in 1, 2, or sometimes even 3 hours. On some nights, particularly when the water surface was rough, aggregation would not take place. At first fish would splash, at the surface, on the periphery of the illuminated water. After a short time alewives would move in and out of the illuminated water, and concentration would begin at a depth of 10 to 15 feet under the light. Schools would frequently come to the surface and immediately descend to the original depth. It is not known whether the movement of alewives into the illuminated area was an actual tactic response or involved feeding. At times adults were clearly feeding on young-of-the-year alewives. The young of the year were close to the surface, and the adults would ascend for brief intervals to feed. Predation may have been great, but it was inefficient since many "strikes" by adults at young resulted in the young escaping. Small numbers of large common shiners (*Notropis cornutus*) and young American smelt (*Osmerus mordax*) were frequently taken with the alewives. Smelt are usually considered as negatively phototactic.

MASS MORTALITIES

Entrance of alewives into littoral areas may be coupled with mass mortalities. Graham (1956) described the annual mass mortalities of the alewife in Lake Ontario, reviewed literature pertinent to the phenomenon, and suggested lethal temperatures as a causal factor.

Odell (1934a) noted that mass mortality of the alewife occurred only occasionally in Seneca Lake, New York, and suggested that it results from a population imbalance due to large year classes. Gross (1953) reported early summer mass mortalities to be nonexistent in Lake Hopatcong, New Jersey. Residents along Cayuga Lake have reported only occasional mass mortalities, and many have the impression that the frequency of mortalities decreased after intensive stocking of lake trout (*Salvelinus namaycush*) which are extensive predators of alewives. Alewives in the Finger Lakes pass through essentially the same time-space-temperature gradient as those in Lake Ontario.

It seems odd that fish which are capable of discriminating fine differences in temperature should enter and remain in a lethal-level

gradient. Brett (1959) pointed out that fish in nature are usually found well within their zone of thermal tolerance. But Ferguson (1958) showed in laboratory experiments that yellow perch (*Perca flavescens*) entered and remained in lethal temperature gradients; the perch, however, may have been crowded. In another experiment Collins (1952) demonstrated a preference of the alewife for the warmer of two temperature alternatives.

Graham (1956) performed laboratory experiments which indicated that the alewife had an upper lethal tolerance of approximately 23° C. (about 73° F.), but Trembley (1960) reported field observations where alewives were found in a lagoon of the Delaware River which had a temperature gradient from 80° to 90° F. When these alewives were frightened into the warmer water of the lagoon, some died of "heat shock". On July 1, 1961, alewives were observed in daylight in Interlaken Beach Stream which had a surface temperature of 79° F. Discrepancies in lethal temperature reports are probably associated with acclimation phenomena.

Both Graham (1956) and Odell (1934a) noted that some moribund alewives had infestations of *Saprolegnia*. Observations in 1960 were made on the first day alewives entered into shallow water at Interlaken Beach when temperatures of the lake and stream were 48° F. and 57° F., respectively. Schools contained individuals that were moribund and heavily infested with fungus (presumably *Saprolegnia*). Unless the onset of fungus infestation and moribund condition had been instantaneous, mortality-inducing variables must have been operative before the alewives entered the shallow, relatively warm water. The lethal level of temperature at this time, if temperature was the cause of death, could have been no higher than 57° F. Many dead alewives were observed in Cayuga Lake until the middle of July.

In 1961 no dead or dying alewives were observed in Cayuga Lake. The spring warming pattern in 1961 was essentially the same as that in 1960, but it took place about 2 weeks later. Temperature may be a factor in mass mortality of alewives, but other factors are certainly involved.

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SURVIVAL OF BURIED BULLHEADS SUBJECTED TO 4′-IODO-3-NITROSALICYLANILIDE[1]

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ABSTRACT

Brown bullheads from 2.5 to 6 inches long were subjected to solutions of 4′-iodo-nitrosalicylanilide in laboratory jars some of which contained bottom sediments of different depths up to 2 inches. All the experimental fish were killed by 50 ppb of the chemical in both clear and turbid water at 71° and 47° F., but 25 ppb killed only part of them. When thick sediments were available at 47° F., the fish buried themselves and some survived. At 71° F. the fish did not bury themselves and suffered complete mortality. Lodgment in sediments or other protective niches is probably responsible for much of the survival of fish during reclamation work.

During attempted chemical eradication of fish from lakes some individuals often survive, and this results in quick repopulation. The brown bullhead (*Ictalurus nebulosus*) sometimes survives rotenone poisoning, probably not because of physiological immunity but rather as a result of its habit of submerging itself in bottom sediments. Loeb (1964) showed that in the laboratory the frequency and duration of burial in sediments increased while respiration decreased as temperatures were lowered.

Darnell and Meierotto (1965) issustrated the periodicity of the black bullhead (*Ictalurus melas*) in a stream pond. The absence of young and adults from traps during certain hours suggested that they were buried at these times. Theoretically, buried fish would survive a short-term poison more frequently than those in open water, especially at low temperatures. The mechanism of survival is unknown but might include lower metabolism and rate of respiration, less contact with the poison due to immobility, filtering of poison by sediments, and so on.

The purpose of this paper is to illustrate just such survival in the presence of 4′-iodo-3-nitrosalicylanilide (Figure 1) when brown bullheads are able to submerge themselves in bottom sediments. Piscicidal activity attributed to this substance has been documented by Starkey and Howell (1965), Starkey and Loeb (1965), and Walker, Starkey and Marking (1966).

The chemistry and biological activity of variously substituted 3-nitro- and 5-nitrosalicylanilides has been described by Taborsky, Darker and Kaye (1959); Taborsky and Starkey (1962, 1963); Star-

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R. Henry A. Regier of the New York Cooperative Fishery Research Unit at Cornell University assisted with biometrical analysis.

key and Howell (1965); Starkey and Loeb (1965); and Walker, Starkey and Marking (1966). This series, characterized by the presence of an *ortho* hydroxyl phenolic group and a nitro substituent at the 3 or 5 position of the carboxylic acid moiety, consists of compounds differing by the locus and species of halogenated and non-halogen-

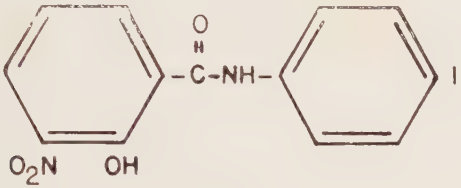

Figure 1. Structure of 4′-iodo-nitrosalicylanilide molecule.

ated substituents in the aniline moiety. They are beige to yellow in color, nearly insoluble in water at neutrality, slightly soluble (0.005 per cent) under alkaline conditions, and highly soluble in acetone, N,N-dimethyl-formamide, and dimethylsulfoxide. Rate of detoxification in water is relatively slow.

METHODS

The chemical was dissolved in dimethylsulfoxide for all studies. One set of tests was run in spring water having a pH of 7.8, but in most tests clear spring water with a pH of 6.3 and low mineral content was used. Temperatures were 47° and 71° F. ±1° and at both the water was clear or made turbid by bottom sediments up to 2 inches deep. The sediments were either gelatinous organic material from a lake bottom or a mixture of gelatinous and fibrous organic material and silt and clay.

Volumes used were 3, 19 and 72 liters. The amount of fish flesh per liter of water was necessarily high in the smallest containers but was held to 2.5 and 0.6 grams per liter at 47° and 71° F., respectively, in the larger containers. At 71° F. all fish used were about 2.5 inches in total length; at 47° F. they ranged from 2.5 to 6 inches. The fish were acclimated without food to the test temperatures for at least 60 hours before testing. The experimental solutions were not aerated.

Control tanks replicated the tests in every respect except for the poison. Only testing during which all control fish survived is reported. Selection of this sort might bias results in favor of mortality in the experimental fish if deaths had been random between them and the control fish and not due to the chemical. Such, however, was not the case. In only one instance, involving three control

fish at 50 ppm and 71° F., did control fish die, and this was attributed to heavy growth of an unidentified organism.

TOXICITY AT 71° F.

In clear water at 71° F., 50 to 1,000 ppb of the chemical killed all small bullheads, whereas 25 ppb caused little mortality in 4 days (Table 1). At this temperature 50 ppb killed all fish in from 8 to less than 48 hours and was close to the minimum concentration required to do so.

At a concentration of 50 ppb, the chemical maintained its toxicity to bullheads in clear water for at least 4 months (Table 2), but it became relatively nontoxic after a month when 2 inches of bottom sediments were present. In this series, five small bullheads were added at intervals to each of paired sets of 19-liter jars; one jar of each set contained clear water plus chemical and the other had gelatinous and fibrous organic material in addition. The 10 jars were thoroughly stirred once only to mix the poison. In about a day the sediment-containing jars cleared; therefore, detoxification was due to sediment, not turbidity. A characteristic chemical odor disappeared

Table 1. Toxicity of 4′-iodo-3 nitrosalicylanilide to Small Bullheads in Clear Water at 71° F.

Concentration (ppb)	Volume (liters)	Number of fish	Mortality or survival in hours	Mortality rate (per cent per hour)
1,000	3	2	2 dead in 0.6	100
100	3	3	3 dead in 6	16
100	19	6	6 dead in 3	33
100	19	6	6 dead in 3	33
100	19	3	3 dead in < 5	>20
100	72	20	20 dead in <24	> 4
75	72	20	20 dead in < 3	>33
50	3	3	3 dead in 10	10
50	3	3	3 dead in <46	> 2
50	19	3	3 dead in 11	9
50	19	3	3 dead in 8	12
50	19	3	3 dead in 8	12
50	19	3	3 dead in 8	12
50	19	3	3 dead in 8	12
50	19	5	5 dead in <24	> 4
50	72	20	20 dead in <48	> 2
25	3	3	1 alive at 53	1
25	19	6	6 alive at 75	0
25	19	6	6 alive at 75	0
25	72	20	19 alive at 96	< 1

Table 2. Comparative Loss of Toxicity of 50 ppb of 4'-iodo-3-nitrosalicylanilide in Clear Water or in Presence of 2 inches of Bottom Sediments at 71° F.*

Days after introduction of chemical	Mortality or survival	
	Clear jars	Bottom sediments§
0	5 dead in <24 hours	5 dead in <24 hours
11	5 dead in <42 hours	5 dead in <18 hours
32	5 dead in <41 hours	5 alive at 11 days
43	5 dead in < 4 days	2 alive at 14 days
123	5 dead in <24 hours	5 alive at 8 days†

* In each test 19 liters of solution and five small bullheads were used.
§ No fish buried themselves.
† At 8 days the mud was stirred thoroughly but the fish were not affected at termination several days later.

TABLE 3. DATA * FOR TESTING HYPOTHESES

Days after introduction of chemical	Average number dying per day		Relative mortality rate§
	Clear jars	Sediment jars	
0	5.0	5.0	1.00
11	3.3	7.5	2.25
32	2.9	0	0
43	1.25	0.21	0.17
123	5.0	0	0

* Converted from data in Table 2.
§ Average for sediment jars divided by that for clear jars.

from nontoxic jars. Since no bullheads buried themselves at 71° F., survival after 32 days can be attributed solely to breakdown of the chemical. As would be expected, higher concentrations (100, 500 and 1,000 ppb) detoxified at a slower rate.

The data in Table 2 were converted to minimum average mortality rates (Table 3) for statistical testing. Three hypotheses were tested: (1) that mortality rates were equal in the clear and the sediment-containing jars; (2) that there was no progressive change in toxicity as time increased; and (3) that there was no net effect of sediment on toxicity as time increased. Hypothesis 1 was tested with the Wilcoxon matched-pairs signed-ranks test, and Hypotheses 2 and 3 were tested with the Spearman rank correlation test (Siegel, 1956). All tests indicated non-significance at the 5 per cent level. Thus, although inspection of the data suggests that the three hypotheses are in fact wrong, the tests indicated either that the differences were

due to chance or that there were not sufficient data to rule out chance as an adequate explanation.

The latter is the more probable, however, and it is likely that a larger sample would have shown significant differences. When viewed in context with Table 1, where all fish died in concentrations of 50 ppb, the data in Table 3 appear more significant. And, too, the chemical odor of 4′-iodo-3-nitrosalicylanilide had disappeared from the jars in which fish lived but not from those in which fish died. The data also appear to show that the chemical was toxic to bullheads after 11 days in the presence of sediments, even at 71° F. This is of significance when applied to the data in Table 7; those data show that buried bullheads survived when the solutions above them must have been toxic.

An additional test at 71° F., in clear water and involving 18 small bullheads, showed that fish could survive an exposure of at least 4 hours to 50 ppb of the chemical. Nine fish removed (three at a time) to fresh water after 1, 2 and 4 hours, respectively, survived, whereas the other nine fish died after 7 hours exposure. It is possible that at the higher temperatures lack of or infrequent submergence in bottom sediments might contribute to bullhead mortality even in the presence of rapidly degrading poisons. It is also a possibility that chance location of fish in cooler springs or estuaries might contribute toward burial and survival. Little is known, however, about the temperature preferences of bullheads or their burial habits under natural conditions.

TOXICITY AT 47° F.

At 47° F. concentrations of 50 to 100 ppb of the chemical killed all small bullheads in both clear and turbid water, while a concentration of 25 ppb was ineffective (Table 4). The turbid tanks contained only 0.1 inch of gelatinous organic material, and thus most of the fish were probably unable to bury themselves. Two spring water supplies with different pH values were used for these tests and this might have caused some variation in results. It should be noted that one fish lived for almost 5 days at 50 ppb in a turbid tank; this might have been due to resistance, chance burial in a thicker portion of sediment, or both.

Tests in 19-liter jars containing only 0.25 inch of gelatinous and fibrous organic material showed that concentrations of 50 and 60 ppb could quickly kill all fish despite the fact that they were buried (Table 5). All of the small fish were buried in the thin sediment with only the lips showing when the poison was added and they remained there for at least 7 hours. These fish died within 24 and 46 hours at 60 and 50 ppb, respectively.

TABLE 4. TOXICITY OF 4′-IODO-3-NITROSALICYLANILIDE TO SMALL BULLHEADS IN CLEAR WATER AND TURBID WATER AT 47° F.*

Concentration (ppb)	Mortality§ or survival	
	Clear water (pH 7.8)†	Turbid water (pH 6.3)
00		20 dead in <24 hours
00	15 dead in <24 hours 20 dead in <30 hours	
75		19 dead in <24 hours 20 dead in <48 hours
75	8 dead in <24 hours 20 dead in <60 hours	
50		13 dead in <24 hours 19 dead in < 4 days 20 dead in < 5 days
50	20 alive at 24 hours 20 dead in <72 hours	
50‡	3 dead in <24 hours	
25		20 alive at 48 hours 3 dead in 7–24 days
25	20 alive at 72 hours 9 dead at 8 days	

* In all tests but one 72 liters of solution and 20 small bullheads were used.
§ Figures for number dead in each test are cumulative.
† One test at a pH of 6.3.
‡ In this test 19 liters of solution and three small bullheads were used at a pH of 6.3.

TABLE 5. EFFECT OF 4′-IODO-3-NITROSALICYLANILIDE ON SMALL BULLHEADS THINLY BURIED IN 0.25 INCH OF BOTTOM SEDIMENTS AT 47° F.*

Concentration (ppb)	Mortality in hours§
0	5 dead in <22
0	5 dead in <22
0	5 dead in <22
0	4 dead at 22 5 dead at 24
0	4 dead in <22 5 dead at 30
0	4 dead in <22 5 dead at 24
0	5 dead in <22
0	3 dead in <22 4 dead at 26 5 dead in <46

* In each test 19 liters of solution and five small bullheads were used.
§ Figures for number dead in each test are cumulative.

Studies to determine the rate of detoxification of the chemical t 47° F. (Table 6) were similar to those run at 71° F. In clear irs, a concentration of 50 ppb quickly killed all small bullheads even

Table 6. Comparative Loss of Toxicity of 50 ppb of 4'-iodo-3-nitrosalicylanilide in Clear Water or in Presence of 2 Inches of Bottom Sediments at 47° F.*

Day after introduction of chemicals	Mortality or survival	
	Clear jars	Bottom sediment§
0	5 dead in 28 hours	3 dead in 28 hours 2 alive and buried at 11 days
11	5 dead in <46 hours	5 dead in <46 hours
31	5 dead in 41 hours	1 dead in 41 hours† 2 alive and swimming at 41 hours 2 alive and buried at 41 hours

* In each test 19 liters of solution and five small bullheads were used.
§ Terminated at this point (first indication of survival due to burial).
† Terminated at this point.

after the solution had stood for 31 days before introduction of the test fish. In the fresh solution in a sediment-containing jar, two bullheads buried themselves and survived for 11 days and might have lived longer if the test had not been terminated; these fish were not seen during the 11 days so it is assumed that they were buried most of the time. That the solution was toxic after 11 days was illustrated by the quick death of fish introduced at that time into the second set of jars. The results of the test at 31 days were inconclusive. These data were the first indication of a correlation between burial (in thick sediments) and survival, and as a result the relationship was investigated further.

EFFECT OF BURIAL ON SURVIVAL

Three series of tests in 72-liter tanks showed that brown bullheads were able to survive 50 and 60 ppb of the chemical at 47° F. if they had access to thick bottom sediments (Table 7). The fish used were 2.5 to 6 inches long. The first test involved a concentration of 60 ppb and 15 fish. Three fish were placed in each of five tanks containing 2 inches of gelatinous organic material and were allowed to acclimate themselves for a week before introduction of the poison; during this time the water cleared and it could be seen that many of the fish were buried at any instant. Thirteen of these fish died 20 to 26 hours after addition of the chemical, but two were alive and buried when the tanks were emptied 10 days later. Frequency, duration and position of burial were unknown; since they were not seen swimming at any time between the second and tenth days it is assumed that the

TABLE 7. EFFECT OF 4′-IODO-3-NITROSALICYLANILIDE ON BURIED AND UNBURIED SMALL BULLHEADS AT 47° F.

Concentration (ppb)	Number of fish	Mortality or survival		Statistical trial
		Buried*	Screened and unburied	
50.....	15	13 dead in 26 hours 2 alive at 10 days	..	..
50.....	18	14 dead in 2 days 4 alive at 8 days	..	A
50.....	18	..	18 dead in 23 hours	
50.....	30	26 dead in 7 days 4 alive at 16 days	..	B
50.....	30	..	30 dead in 20 hours	

* Not all of the fish were buried at one time, but all fish alive at termination of tests were buried. At no time was a dead fish found buried.

fish were buried most of the time and that this contributed to their survival.

In two additional studies half of the fish were prevented from touching the bottom sediments by fiberglass screens, and these were killed in a day by 50 ppb of the chemical (Table 7). Some buried fish survived until termination of the experiments at 8 and 16 days. The water remained turbid throughout these observations so survival and mortality differences were not directly caused by this factor. The fish were acclimated to the test conditions for a week before addition of the poison.

In the first of these tests, employing gelatinous organic material and 36 fish, the 18 screened fish and 14 of the buried fish died quickly. Two small and two medium-sized bullheads were buried and alive when the tanks were emptied at 8 days. Frequency, duration and position of burial were unknown.

The second test involved 60 fish and sediments comprised of a mixture of gelatinous and fibrous organic material, silt and clay. The 30 screened fish and 12 of the buried fish died in a day. Of the buried fish, 19 died in 4 days and 26 by 7 days. At 16 days the remaining fish, two of medium and two of small size, were alive and buried; three of them were seen swimming on the 13th day so obviously burial was not continuous.

The data in Table 7 were used to test the hypothesis that equal proportions of the trial lots died from the poison whether or not they were permitted to bury themselves. Since the experimental con-

ditions of Trial A were somewhat different from those in Trial B, each was tested separately; the data were then lumped for a combined test. The Fisher exact probability test (Siegel, 1956; Steel and Torrie, 1960) was used. The probability that the outcome of Trial A was due purely to chance was calculated as 5.2 per cent, that of Trial B as 5.6 per cent and that of Trials A and B combined as 0.3 per cent. The inference is that availability of thick sediments in which bullheads may bury themselves significantly reduces the effectiveness of the chemical at 50 ppb and 47° F.

It should be noted that dead bullheads were never found submerged in the bottom sediments during any of the tests, but rather on the bottom or at the surface. Obviously those buried fish which were adversely affected by the poison emerged into and died in open water. At the same time it appears that a combination of natural resistance and protection by burial allowed some fish to survive.

DISCUSSION

Few of the observations were originally made for the purpose of determining the effect of burial on survival: therefore, the data are less ordered than would otherwise be the case. However, they show that brown bullheads were always killed by 4'iodo-3-salicylanilide at a concentration of 50 ppb in both clear and muddy water and at temperatures of 47° or 71° F. Addition of 2 inches of bottom sediments did not allow fish to survive at the higher temperature of 71° F. probably because they did not bury themselves. At 47° F., many bullheads buried themselves in the bottom sediments and some survived for 8 to 16 days while all unburied fish died within several days. The surviving and buried fish might have lived until the poison detoxified at some point after 31 days if the tests had not been terminated.

In the field, where large numbers of bullheads in a population might be buried at any instant, quite a few might survive attempts at poisoning. Hypothetically, the survival value of burial would be increased in the vicinity of springs or in estuaries of tributary streams. In both circumstances the concentration of poison in the overlying water would be constantly lessened.

It can be hypothesized that other species of fish and other forms of life escape death by burial, or by inhabiting, for some of the time at least, other protective niches that are not penetrated by the maximum concentration of poison or in which the initial concentration is constantly diluted. A few individuals might survive until the body of water as a whole became relatively nontoxic.

Obviously, an arsenal of poisons to be used as reclamation tools

should include a wide spectrum with respect to rate of detoxification. When escape habitat is available and a complete kill is desirable, a short-term poison will not do. Accordingly, it will probably be necessary for much future reclamation work to be repeated at frequent intervals since it will be undesirable to maintain quality waters in toxic condition.

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GROWTH AND AGE OF WINTER FLOUNDER IN FOUR BAYS OF LONG ISLAND[1]

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ABSTRACT

Otoliths from 2,400 adult and 620 juvenile winter flounder were collected by otter trawl and haul seine in several south-shore bays of Long Island (N. Y.). Measurements to annuli and otolith edge were analyzed to determine when annuli formed and their usefulness as criteria of age. Selected data were treated statistically, and it was found that the length attained at specific ages differed significantly between certain of the bays. Age composition of the population also differed significantly between the bays in all but one case. Both differences resulted in populations of generally larger-sized fish in the more eastern bays.

Age and growth studies of the winter flounder, (*Pseudopleuronectes americanus*), as reported upon by Lobell (1939), presented evidence that growth was faster in Peconic Bay than in Shinnecock and Moriches Bays and western Long Island Sound. Lobell's conclusions were based upon scale readings of age. A later report by Neville and Perlmutter (1940) stated that winter flounder in western Long Island Sound grew at slower rates than in other localities of Long Island. Data pertaining to length according to age and sex were tabulated for specimens from Long Island Sound, Peconic Bay, Block Island Sound, Great South Bay and Moriches Bay. The authors did not specify how age was determined, but Perlmutter (personal communication) reported that scales were used. Neither report gave supporting data to describe the formation of the annulus, nor were the conclusions based on statistical analyses. Lobell (1939) did not separate his data by sex, and, because of different growth rates for the sexes, some doubt arose concerning his statements that flounder grew faster in one locality than another.

The management possibilities of the winter flounder fishery were outlined by Perlmutter (1947). Such management requires accurate information on age composition and growth in addition to other essential data. Therefore, further study was undertaken in several south-shore bays of Long Island.

METHODS

In each of the years 1961, 1962 and 1963 the populations of winter flounder in Great South Bay, Moriches Bay, Shinnecock Bay and Peconic Bay were sampled. Descriptions of the bays and an illustration of their position and size were presented by Briggs (1965). Dur-

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ing spring and fall, samples were obtained from the adult population with a 3½-inch stretch-mesh otter trawl which had a 60-foot head rope and a 3-inch cod end. Measurements to the nearest half centimeter were obtained for 100 adult fish in each bay in each season. The fish were sexed by internal examination, and otoliths (left sagitta) for age determination were removed and stored in a 3 per cent solution of sodium phosphate. In spring, summer and fall, the juvenile populations were sampled with a 300-foot haul seine of mesh ranging from 1⅛ inches in the wings to ⅛ inch in the bunt. Random samples of juvenile fish were measured to the nearest half centimeter every four weeks in each of the bays. Otoliths were removed and stored for a stratified sample of 10 juveniles from each bay every four weeks in 1961 and 1962, and every eight weeks in 1963. At the termination of field work in the fall of 1963, data and otoliths were available from 2,400 adults and 620 juveniles.

Otoliths were immersed in gylcerin for clearing at least 24 hours before examination with a binocular microscope. The left otolith was placed concave side uppermost in a hanging drop slide with the narrower end of the long axis away from the observer. The otolith was covered with glycerin. Measurements to annular markings and to the lateral edge were recorded along the imaginary line from the center of the opaque core to the widest point of the left margin of the otolith. Measurements in units equal to 0.048 millimeter were recorded at 9x magnification with the aid of an eyepiece micrometer. Light from a microscope lamp was reflected through the otolith by using the concave microscope mirror. To achieve the proper illumination, the iris diaphragm was half closed and the mirror was manipulated until the reflected light passed through the otolith in such a manner as to make the annular markings, other than the first, appear as pencil-line-thin brown lines. All readings were taken without knowledge of the sex or size of the fish. After all the adult specimens for one season in a particular bay had been read, the readings were repeated, and, when the two did not agree, readings were continued until one was decided to be the best. For juvenile fish, the same procedure was followed, but on a yearly, rather than seasonal, basis.

FINDINGS

The data were analyzed to evaluate the otolith as an index of age and to determine what features offer the most useful criteria. These were then used to classify the flounder collected according to age as a basis for comparing population composition and length attained at specific ages.

The Otolith as an Index of Age

The otolith of the winter flounder has been used previously in five studies of winter flounder. Landers (1941) examined otoliths from Point Judith Pond and Mount Hope Bay in Rhode Island and described their appearance and size in fish ranging upwards from 6.6 centimeters in length. He concluded that "the alternate dark and light bands on the earbone represent winter and summer growth, respectively". He judged the age of his specimens on this basis and prepared tables of length and age as of November when his collections were made. The data were not separated by sex.

Warfel and Merriman (1944) used the otolith to distinguish the age of juvenile winter flounder taken by shore seining in Connecticut. No description of the annular markings upon which ages were determined was given.

Berry (1959) described in detail the seasonal occurrence of opaque and hyaline bands within the otolith from fish taken in Rhode Island waters. According to his analysis, young of the year form several alternating bands during their first summer. The first opaque band which is useful for judging age forms in October and continues its growth until July. At this time, when the fish is several months beyond 1 year of age, a hyaline band is formed which persists until the winter or spring of the following year. From 2 years of age on, opaque bands are formed from April to August and hyaline bands during the remainder of the year. Berry concluded that, since the beginning of the opaque band is associated with the spawning season and formed each year at the same time, it is a convenient mark of age. He determined the age of winter flounder samples collected in Rhode Island and computed growth equations for both sexes. From these, the predicted growth of male and female fish was calculated.

Pearcy (1962) used the otolith in his study of juvenile winter flounder in the Mystic River estuary in Connecticut. His observations supported Berry's (1959) conclusions concerning the time of deposition of opaque and hyaline bands.

Matthiessen and Wilbour (1963) prepared an approximate growth curve based on otolith readings. This curve combined data for both male and female winter flounder.

In the present study, otoliths of winter flounder appeared to have alternate bands of opaque and hyaline growth when no reflected source of light was used. However, it was not possible, using any power of magnification, to determine the number of bands accurately, except for fish 2 years old or less. For this reason, reflected light was used, causing annular markings other than the first one to appear as thin brown lines. Because the appearance of these annular markings did not agree with Berry's (1959) description of the opaque bands

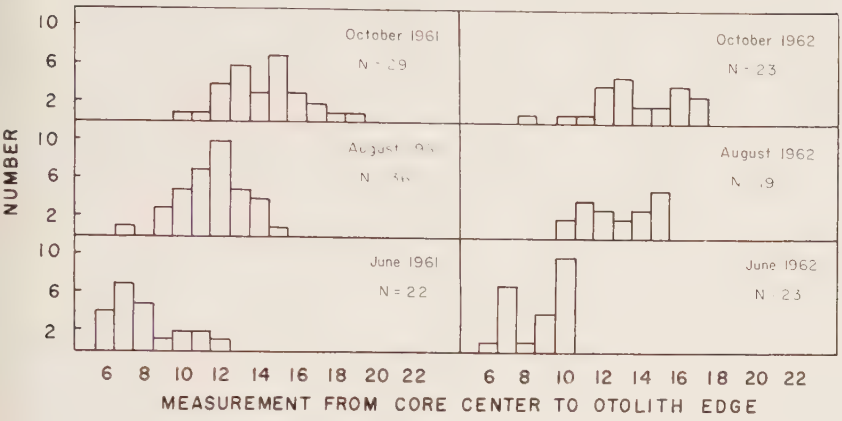

Figure 1. Frequency according to measurement from core center to edge for otoliths which had no annulus. Unit of measurement =0.018.

of growth, measurements to the annuli and to the otolith edge were recorded to determine their usefulness in judging age, i.e., the data were treated to investigate the occurrence of these markings each year at approximately the same time.

Measurements to the edge of otoliths which had no annulus are presented in Figure 1. These otoliths were collected from winter flounder taken in all bays by haul seine in the summer and autumn of 1961 and 1962. In both years, the otoliths increased in size as the fish grew, and data from the autumn samples indicate that the first annulus, if formed in winter or early spring, should appear at a distance of approximately 10 to 20 units from the center of the core. The extended spawning season, reported by Perlmutter (1939), Bigelow and Schroeder (1953) and Pearcy (1962), is apparently reflected in the wide range of measurements in otolith width.

This poses a question regarding the age of winter flounder without an annulus, for it is possible that several years of growth occur before annulus formation. To be certain of assigning proper ages to such specimens, fish lengths observed in the present study were compared with data recorded by others. Collections by Perlmutter (1939) indicated that young of the year in October attained total lengths of approximately 7 to 11 centimeters. Warfel and Merriman (1944) and Bigelow and Schroeder (1953) presented data similar to those of Perlmutter. Pearcy's (1962) research, however, was found the most useful, for his intensive study of larval growth indicated that his classification of young of the year was correct. He reported that the average standard length in the fall of the year was approximately 60 millimeters. Since this average approximates the average lengths at

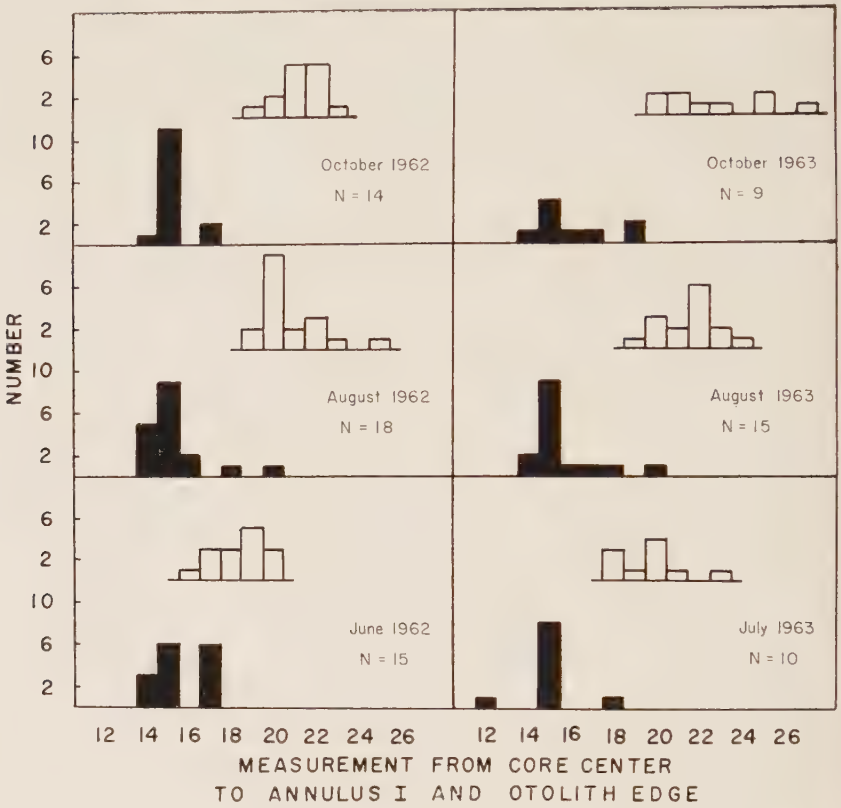

Figure 2. Frequency according to measurements from core center to Annulus I (solid bars) and to edge (open bars) for otoliths of juvenile fish with one annulus. Unit of measurement =0.048.

this season for fish classified as young of the year in the present study, it seems apparent that the assigned ages were correct.

Figure 2 presents the distribution of measurements to the line of demarcation between opaque and hyaline growth (annulus I) and to the otolith edge for juvenile fish with one annulus. These were collected in 1962 and 1963 by haul seine in the shallow shore zone. The data show that annulus I appeared at the predicted distance from the center of the core. It occurred each year and at approximately the same time, for increments of hyaline growth increased in both years as the summer season progressed. The annulus did not shift its position within this summer period.

Otoliths with one annulus were examined from winter flounder caught by otter trawl during the spring in the relatively deeper waters of the bays. Measurements to the annuli and the otolith edge for these fish are presented in Figure 3. They demonstrate that these fish

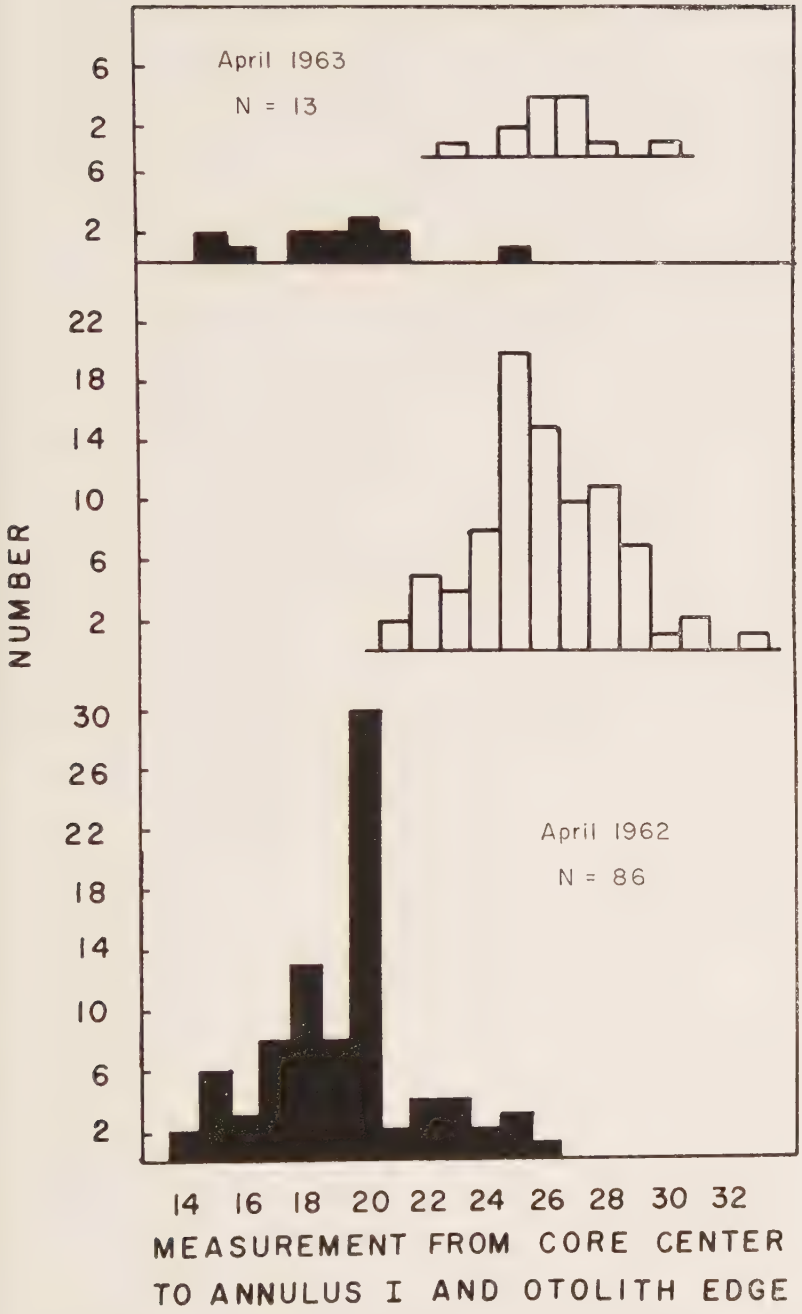

Figure 3. Frequency according to measurements from core center to Annulus I (solid bars) and to edge (open bars) for otoliths of fish taken during spring that had one annulus. Unit of measurement =0.048.

and the fish with one annulus taken by haul seine did not belong to the same year class. The measurements to the otolith edge for shore-zone samples with one annulus in early summer ranged from 16 to 23 units. Similar measurements for fish taken in deeper water with one annulus in the spring ranged from 21 to 33 units. It is apparent from these data that the hyaline growth continued, beyond the formation of annulus I at age I, through the summer and fall and into the winter and early spring at which time the fish were 2 years old.

Further examination of Figures 2 and 3 reveals that the opaque region encompassed by annulus I increased in size after the second summer of life of the fish. Such an increase does not affect the usefulness of the annulus as an index of age. However, proper age designation requires consideration of the otolith width, for in actuality a winter flounder with one annulus may be 1 or 2 years old. Fortunately, age determination is somewhat simplified by the habits of the fish and the gear used to sample a population. In general, juvenile winter flounder (young of the year and 1 year olds) inhabit the shore zone, whereas older fish frequent the relatively deeper waters of the bay. Although not common in deeper water, juvenile fish are present, but in this study they were seldom taken in trawl samples because the mesh size allowed them to escape.

To determine the usefulness of annulus II as an index of age, increments beyond this mark were analyzed for spring and fall collections from Great South Bay. Data for otter trawl samples in 1961, 1962 and 1963 were combined. Separation of the data into increment groups of 2 units or less and of more than 2 units revealed that a greater proportion of small increments occurred in fall. The difference between spring and fall collections in the proportion of small increments was highly significant ($<.01$). There is evidence, then, that annulus II forms subsequent to spring and prior to fall and that it can be used for age determination.

Hyaline increments beyond annulus III were so small that it was not possible with such data to find evidence of the mark's validity as an index of age. However, analysis presented later in this paper shows that fish size increased as the number of annuli increased. For older age groups, this relationship must suffice as evidence of the validity of annuli as yearly marks.

Evidence in the present study indicates that annulus formation as described by Berry (1959) is essentially correct. One minor difference was noted. He reported that hyaline growth in 1-year-old fish begins in July, whereas the data for Long Island fish revealed that hyaline growth was well advanced in late spring. This difference does not affect age estimates.

LENGTH AT SPECIFIC AGES AND POPULATION COMPOSITION

With knowledge of the manner in which the otolith develops, it was relatively easy to determine the age of the fish. Specimens from the shore zone were assigned ages equal to the number of annuli. Those taken from deeper waters in the spring were assigned ages equal to the number of annuli plus 1. Trawl samples taken in the fall were not used for analysis of variance because of the difficulty in judging age correctly for such fish. This difficulty was due to not being able to determine in some instances whether or not any opaque summer growth had been deposited on the otolith edge.

To investigate the length attained by young of the year in the four bays, the fish collected from the shore zone in October 1962 were assigned ages, and the data for length for the 379 specimens in age 0 were treated by analysis of variance (Table 1). No significant differ-

TABLE 1. ANALYSIS OF VARIANCE FOR DATA ON LENGTH OF YOUNG-OF-THE-YEAR WINTER FLOUNDER

Source of variation	Sum of squares	Degree of freedom	Mean square	*F*	*F* (0.01)
Between samples	319	3	106.3	1.2	6.4
Within samples	3285	375	87.6		
Total	3604	378			

ence between sample groups was found, indicating that there were no growth differences among the young of the year in these bays. However, because the data were not separated by sex, this conclusion is tentative.

To investigate the growth of older winter flounder, ages were assigned to fish collected by otter trawl during the spring in 1961, 1962 and 1963. The data were separated by bay, sex and age group (Tables 2 to 5). Because of the small number of specimens in certain age groups, it was necessary to use data for ages III and IV only in an analysis of variance of fish length. For each of these in each bay random subsamples of 16 were taken for each sex. The analysis (Table 6) revealed that fish size increased as the number of annuli increased. It also gave evidence that females grew at significantly greater rates than males and that the fish at specific ages from the four bays were not drawn from the same population. To determine in which of the bays the difference in length attained was significant,

TABLE 2. DISTRIBUTION ACCORDING TO LENGTH FOR ADULT WINTER FLOUNDER OF VARIOUS AGES TAKEN IN GREAT SOUTH BAY

Length in half centimeters	Age group and sex									
	II		III		IV		V		VI	
	M	F	M	F	M	F	M	F	M	F
33	..	1	..	..	..	..	..	..	..	..
34	..	..	1	..	..	..	..	..	..	..
35	..	1	..	..	..	..	..	..	..	..
36	..	1	..	..	..	..	..	..	..	..
37	1	..	..	..	..	..	..	..	..	..
38	..	1	..	..	..	..	..	..	..	..
39	..	..	..	..	1	..	..	..	..	..
40	..	4	..	2	..	..	..	..	..	..
41	1	3	..	1	1	2	..	..	..	..
42	..	3	2	1	1	..	..	..	..	..
43	..	4	1	2	1	..	..	..	..	..
44	..	2	2	2	..	1	..	..	..	..
45	..	2	1	5	1	..	..	..	..	..
46	..	2	2	6	4	..	..	..	..	..
47	..	..	3	11	3	1	..	..	..	..
48	..	2	..	10	3	..	1	..	..	..
49	..	1	1	14	1	..	..	..	..	..
50	..	..	..	3	2	..	..	..	..	..
51	..	..	1	7	3	3	1	..	..	..
52	..	..	1	5	1	6	1	..	..	1
53	..	..	1	8	2	2	..	..	..	..
54	..	..	1	6	..	6	1	..	..	..
55	..	..	2	4	..	5	2	..	..	..
56	..	..	1	3	1	1	..	..	..	..
57	..	..	2	5	2	4	..	2	..	..
58	..	..	..	1	..	3	..	1	..	..
59	..	..	2	3	..	5	..	..	..	..
60	..	..	..	..	..	2	..	1	1	..
61	..	..	..	..	..	3	..	1	..	..
62	..	..	..	..	..	2	..	..	..	..
63	..	..	..	..	..	5	..	..	..	1
64	..	..	..	..	..	..	..	1	..	..
65	..	..	..	..	..	2	1	1	..	1
66	..	..	..	..	..	1	..	..	..	..
67	..	..	..	2	..	..	..	1	..	..
68	..	..	..	..	..	..	..	1	..	1
69	..	..	..	1	..	..	..	1	..	..
70	..	..	..	..	..	..	..	..	..	..
71	..	..	..	..	..	1	..	..	..	..
72	..	..	..	..	..	..	..	..	..	..
73	..	..	..	..	..	..	..	..	..	..
74	..	..	..	..	..	..	..	..	..	..
75	..	..	..	..	..	..	..	..	..	..
Total	2	27	24	102	27	55	7	10	1	4
Mean Length	39.0	42.1	49.3	50.5	48.5	56.5	54.3	62.6	60.0	62.0

a test of critical differences was undertaken using the following equation

$$d = t\sqrt{\frac{2 \times \text{mean square within subclasses}}{n}}$$

$$= 2.58\sqrt{\frac{2\,(30.1)}{64}}$$

$$= 2.50$$

TABLE 3. DISTRIBUTION ACCORDING TO LENGTH FOR ADULT WINTER FLOUNDER OF VARIOUS AGES TAKEN IN MORICHES BAY

Length in half centimeters	Age group and sex											
	II		III		IV		V		VI		VII	
	M	F	M	F	M	F	M	F	M	F	M	F
44	1											
45		2										
46		2										
47		3			2							
48		6	1									
49		8		1	2	1						
50		4										
51	1	5	1	1	1	1	2					
52		5	4	3	4		3					
53	1	4	2	5	1		4					
54	1	2		4	7	2	1		1			
55		1		4	5	2	3				1	
56			6	4	5	1	2		1			
57	1	1	2	1	4	1	9					
58		2		7	3	5	2					
59				8	2	1	1		1			
60			2	3	1	3	1			1		
61				1	1	8	3			1		
62			2	4		2						
63				1	2	2	2	1				
64			1		1	2						
65					1	2				1		
66												
67								1				
68				1								
69						1						
70						1						
71										1		
72												
73												
74												
75												
Total	5	45	21	48	42	35	33	2	3	4	1	
Mean length	51.8	50.4	55.8	57.0	55.5	59.9	56.3	65.0	56.3	64.2	55.0	

Table 4. Distribution According to Length for Adult Winter Flounder of Various Ages Taken in Shinnecock Bay

Length in half centimeters	Age group and sex									
	II		III		IV		V		VI	
	M	F	M	F	M	F	M	F	M	F
48	..	1	..	..	..	..	..	..	..	..
49	..	1	..	..	..	..	..	..	..	..
50	..	..	..	..	..	..	..	..	..	..
51	..	3	..	..	..	..	..	..	..	..
52	2	2	1	..	..	..	..	..	..	..
53	..	1	3	1	1	..	..	..	..	..
54	..	..	5	1	..	..	..	..	..	..
55	..	2	4	4	1	..	..	..	..	..
56	..	3	1	4	5	..	..	..	..	..
57	..	1	4	3	3	..	1	..	..	..
58	..	3	6	9	1	1	1	..	..	..
59	..	..	3	4	5	1	2	..	..	..
60	..	3	3	2	6	1	2	..	..	..
61	..	..	4	5	2	5	5	..	..	..
62	..	..	3	4	8	3	7	1	1	..
63	..	..	..	3	6	4	1	..	..	..
64	..	..	2	2	2	5	2	2	..	..
65	..	..	..	8	1	2	1	1	..	..
66	..	..	1	1	1	6	1	1	..	..
67	..	..	..	1	..	7	1	1	..	..
68	..	..	..	1	..	5	1	..	..	..
69	..	..	1	2	..	2	1	..	1	..
70	..	..	..	1	..	7	..	..	..	..
71	..	..	..	1	..	3	..	1	..	..
72	..	..	..	..	..	3	..	1	..	..
73	..	..	..	..	..	..	..	..	..	..
74	..	..	..	..	..	1	..	..	..	1
75	..	..	..	..	..	1	..	1	..	..
76	..	..	..	..	..	..	..	3	..	..
77	..	..	..	..	..	..	..	..	..	..
78	..	..	..	..	..	..	..	..	..	..
79	..	..	..	..	..	..	..	..	..	..
Total	2	20	41	57	42	57	26	12	2	1
Mean Length	52.0	54.8	58.1	60.9	60.2	66.3	62.2	69.5	65.5	74.0

Values greater than 2.50 would represent a significant difference. The values for the several comparisons are given in Table 7 and reveal significant differences in all cases except for Shinnecock Bay as compared with Peconic Bay.

These findings support those of Berry (1959) that females grow more rapidly than males. Although they are not directly applicable to the work of Lobell (1939) and Neville and Perlmutter (1940), since different bays were compared, they do substantiate the conclusion that the length at specific ages attained by winter flounder

TABLE 5. DISTRIBUTION ACCORDING TO LENGTH FOR ADULT WINTER FLOUNDER OF VARIOUS AGES TAKEN IN PECONIC BAY

Length in half centimeters	Age group and sex											
	II		III		IV		V		VI		VII	
	M	F	M	F	M	F	M	F	M	F	M	F
39		1										
40												
41	1											
42		2										
43												
44												
45		2										
46		1										
47		1										
48		2										
49												
50		2	1									
51		1	1		1							
52		2		1								
53	1	1	1	2	1		1					
54				2			1					
55		2	2		1							
56				1	2							
57		1	2	2	6	2						
58			1	2	1		3					
59	1	1		1	3		2					
60		3	1	1	4		2					
61				4	3	2	2					
62				3	1	3	2	1				
63		1	4	4	3	2	1	2				
64			1	3	2	2	3					
65			2	5	5	3	2	1	1			
66				2		5	2		1			
67				1	1	3		3				
68				2		6		1	1			
69				1		5	3					
70						4		5				
71						2		3				
72						6	1	2				
73				1		1		5	1	1		
74						1		5				
75						4	1	2			1	
76							1	2				
77								1		2		
78					1					1		
79								1				
80										1		
81												
82												
83										1		1
84												
85								1		1		
Total	3	23	16	38	35	51	27	35	4	7	1	1
Mean length	51.0	51.3	58.9	61.8	60.6	67.8	63.4	71.6	68.0	79.0	75.0	83.0

TABLE 6. ANALYSIS OF VARIANCE FOR DATA ON LENGTH OF 3- AND 4-YEAR-OLD WINTER FLOUNDER

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	*F* (0.01)
Age	669.5	1	669.5	32.5**	6.6
Sex	1387.5	1	1387.5	67.4**	6.6
Location	5024.3	3	1674.8	81.3**	3.8
Age-sex	289.1	1	289.1	14.0**	6.6
Sex-location	107.4	3	35.8	1.7	3.8
Age-location	79.3	3	26.4	1.3	3.8
Age-sex-location	104.0	3	34.7	1.7	3.8
Within subclasses	4947.0	240	20.6		
Total	12608.1	255			
Subclass (location)	5024.3	3	1674.8	55.6**	3.8
Within subclasses	7583.8	252	30.1		
Total	12608.1	255			

TABLE 7. CRITICAL DIFFERENCES IN MEAN LENGTHS OF 3- AND 4-YEAR-OLD WINTER FLOUNDER IN THE BAYS STUDIED

Bay	Bay		
	Moriches	Shinnecock	Peconic
Great South	6.2**	10.5**	11.0**
Moriches		4.3**	4.8**
Shinnecock			0.5

** Significant at the 0.01 probability level.

TABLE 8. AGE FREQUENCIES FOR WINTER FLOUNDER TAKEN DURING SPRING IN THE BAYS STUDIED

Age group	Bay			
	Great South	Moriches	Shinnecock	Peconic
I	3	1	0	2
II	29	50	22	26
III	126	69	98	54
IV	82	77	99	86
V	17	35	38	62
VI	5	7	3	11
VII	0	1	0	2
Total	262	240	260	243

can vary significantly in different waters which are closely associated geographically.

Data pertaining to the age composition of winter flounder populations sampled by trawling in each of the bays during spring in 1961, 1962 and 1963 are presented in Table 8. Apparent differences between bays were tested by separating the data for fish less than 5 years old from those for fish 5 years old and older and then testing them by chi-square (Table 9). The differences were highly signifi-

TABLE 9. DIFFERENCES IN PROPORTION OF 5-YEAR-OLD AND OLDER WINTER FLOUNDER IN THE BAYS STUDIED, EXPRESSED AS VALUES OF CHI-SQUARE

Bay	Bay		
	Moriches	Shinnecock	Peconic
Great South	10.21**	6.66**	40.91***
Moriches		0.52	11.48***
Shinnecock			16.20***

** Significant at 0.01 probability level.
*** Significant at 0.001 probability level.

cant, except for Moriches Bay as compared with Shinnecock Bay. Older fish occurred more frequently in each of the eastern bays than in Great South Bay, and more frequently in Peconic Bay than in either Moriches Bay or Shinnecock Bay. Lobell (1939) reported that in 1938 winter flounder in Peconic Bay averaged older than samples taken in Moriches and Shinnecock Bays and western Long Island Sound.

DISCUSSION

Despite the evidence that statistical differences exist in the length at specific ages attained by winter flounder and in the age composition of populations in most of the bays studied, these differences may not be important to the fishery. However, the fish in Great South Bay grow at such a relatively slow rate that they are at least one year behind compared with those in more eastern bays. This difference affects the fishery because, assuming continuation of present conditions with respect to the environment, the fish and the fishery, it appears obvious that the flounder population in Great South Bay, and for that matter in Moriches Bay, will always be composed primarily of smaller fish.

It is interesting to conjecture as to the reasons for the growth variations in winter flounder. Some of the factors which may act

alone or in conjunction with others to produce these variations are genetic differences, environmental differences affecting productivity, differences in competition caused by different population sizes, and differences in salinity per se. In regard to salinity, Deubler and White (1962) have reported that salinity alone influenced the growth of postlarval summer flounder (*Paralichthys dentatus*). Each of the possible reasons for growth variations offer research possibilities.

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THE USE OF SALT-WATER COVES AS WINTER FLOUNDER NURSERY GROUNDS[1]

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ABSTRACT

Data concerning the value of salt-water coves as nursery grounds for winter flounder were recorded in several parts of Shinnecock Bay and Peconic Bay where the shoreline had been little altered and was largely in a natural condition. At each location, paired sampling stations (one in the cove and one in the adjoining main bay) were established. In both bays, the coves were found to be a preferred habitat for young-of-the-year flounder.

In recent years, demand for docking facilities and navigable channels has resulted in alteration of many coves within salt-water bays on Long Island by bulkheading and dredging. Since such changes often completely change the shoreline and water depths, it is possible that they modify the size and composition of marine fish populations which the coves naturally support. There has been no local quantitative study of the use of these coves as feeding or nursery grounds by marine fish of sport or commercial interest, although in general it is known that several of these species frequent the habitat in some degree as young (Greeley, 1939). The purpose of the present study was to measure in a limited way the cove habitat in regard to its value as a nursery ground for the winter flounder (*Pseudopleuronectes americanus*).

Shinnecock Bay and Peconic Bay were selected as study areas because several relatively unaltered coves and main-bay shores were available in each (Figure 1). Sampling stations were, therefore, fairly representative of conditions prior to large-scale alterations. These coves had been dredged at some time for small-boat channels, but the shoreline was largely in a natural condition. There was no bulkheaded property on Red Creek Pond in Shinnecock Bay. Each of the other coves was bulkheaded along 5 per cent or less of the shoreline. Deep-water dredged areas for dock facilities only occurred adjacent to the bulkheads. The coves had bottom material of mud and sand of varying proportions. In general, the littoral and upper (shallow) sublittoral zone was composed of firm sand and mud, beyond which soft mud predominated. Similar zones in the main body of Shinnecock Bay were firm sand and mud, and in the main body of Peconic Bay these zones consisted of the same materials plus large pebbles.

Populations of young-of-the-year winter flounder were sampled with a 300-foot small-mesh haul seine in 1961, 1962 and 1963. The

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

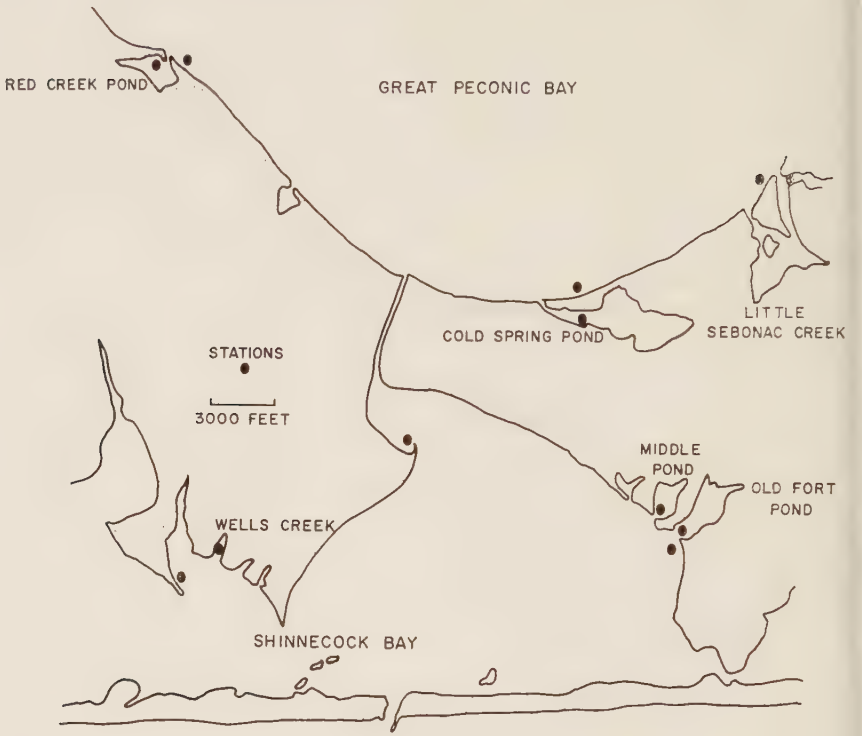

Figure 1. Location of paired sampling stations used.

seine was set from a rowboat in a semicircle with 100 feet of warp at each end of the net. One station in each of three coves in Shinnecock Bay and in three in Peconic Bay were seined every four weeks from June or July to early October. For each cove sample, a paired sample was taken on the same day in the bay. All winter flounder taken at each station were counted, and in most instances all were measured (total length). But, when several hundred were seined at one time at a particular station, a random subsample of approximately 100 was measured. The number of young of the year in the total catch at the station was then estimated by expanding the proportion in the subsample. All fish were released, except for 10 from each sample from which the otoliths were removed. Young of the year were distinguished by otolith examination and by analysis of length-frequency data.

Temperature and salinity were recorded at each station on each sampling day. They ranged within the following values: Shinnecock cove stations, 58° to 80° F. and 25.5 to 31.3‰; Shinnecock Bay stations 57° to 81° F. and 25.5 to 32.2‰; Peconic cove stations, 58° to

TABLE 1. YOUNG-OF-THE-YEAR WINTER FLOUNDER TAKEN BY HAUL SEINE AT PAIRED COVE AND MAIN-BAY STATIONS IN SHINNECOCK BAY

Date	Number per seine haul					
	Old Fort Pond		Middle Pond		Wells Creek	
	Cove	Bay	Cove	Bay	Cove	Bay
1961						
June 9	..	..	..	..	107	0
July 11	..	..	3	74	243	3
August 7	12	41	351	10	138	5
September 8	44	23	14	2	15	0
October 4	220	4	38	1	53	3
1962						
June 13	0	0	1	7	139	8
July 9	25	20	9	18	166	160
August 8	90	119	34	0	59	19
September 12	10	0	72	2	15	78
October 8	9	5	105	2	16	2
1963						
June 7	3	5	29	50	135	3
July 2	86	100	..	76	621	1
30	955	425	..	148	710	30
August 27	8	16	232	2	1,293	113
October 1	34	9	99	8	428	9

84° F. and 24.0 to 29.0‰; Peconic Bay stations, 59° to 83° F. and 24.2 to 29.4‰.

The number of young of the year taken at the various stations are presented in Tables 1 and 2 by date of collection. Usually more young of the year were collected at the cove station than at its paired main-bay station. The data for Shinnecock Bay and Peconic Bay were separated because there were differences in the substratum of the bottom zones. A *t*-test of the paired observations was preformed for each set of data. In each bay, the difference between the numbers of young of the year collected in coves and those collected in the main bay was significant (Shinnecock Bay, $P = <0.01$; Peconic Bay, $P = <0.05$).

During other studies of winter flounder in New York, young of the year were taken occasionally in an otter trawl in Shinnecock Bay and Peconic Bay. Also, recent studies in the Mystic River in Connecticut gave evidence that the deeper sublittoral zone in the estuary is an

Table 2. Young-of-the-year Winter Flounder Taken by Haul Seine at Paired Cove and Main-bay Stations in Peconic Bay

Date	Number per seine haul					
	Red Creek Pond		Cold Spring Pond		Little Sebonac Creek	
	Cove	Bay	Cove	Bay	Cove	Bay
1961						
July 12	..	..	44	1	..	..
August 8	8	156	..	..	12	1
September 7	5	0	..	..	1	0
October 5	2	0	..	..	2	0
1962						
June 12	17	1	38	0	14	1
July 11	14	19	31	0	121	2
August 7	10	0	159	0	57	7
September 11	132	0	13	0	2	2
October 9	28	0	16	0	13	1
1963						
June 6	139	23	5	3	294	0
July 3	12	93	5	..	104	..
July 29	62	44	3	1	20	0
August 26	4	1	18	0	8	0
October 2	18	0	10	0	1	0

important nursery ground for young-of-the-year winter flounder (Pearcy, 1962). Thus it appears obvious that a haul seine, which samples only the littoral and shallow sublittoral zone, cannot be used to obtain data adequate to describe the nursery grounds of this fish. Because of this limitation, it is not possible to evaluate completely the importance of the cove habitat. Nevertheless, the statistical analyses demonstrate that the littoral and shallow sublittoral zone in coves in Shinnecock Bay and Peconic Bay is a preferred habitat for the young of the year. As such, its use as a nursery ground should be considered when large-scale coastal alterations are proposed.

More knowledge is needed concerning the effects of dredging and bulkheading upon marine resources. The data reported here provide information on conditions in these coves prior to extensive changes of this sort.

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A REVIEW OF RESEARCH CONCERNING SUMMER FLOUNDER AND NEEDS FOR FURTHER STUDY[1]

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ABSTRACT

Current knowledge of the summer flounder and its fishery consist of catch data, length-weight relationships and findings from a few studies of life history. Some of this information is useful in describing the fishery, but to a great extent the data provide little that is necessary for evaluating the fishery's effects upon the resource. There is need for: (1) racial studies, initially limited to meristics; (2) a study of larvae and postlarvae by ocean sampling from Nantucket to Cape Hatteras to delineate the early nursery grounds; and (3) a cooperative study of the migratory patterns of immature summer flounder with exploratory efforts confined initially to Pamlico Sound and other appropriate areas of North Carolina.

The summer flounder (*Paralichthys dentatus*) is a high quality fish sought by both commercial and sport fishermen. It is distributed from Provincetown, Massachusetts to Galveston Bay, Texas (Ginsburg, 1952; Poole, 1962). Within this range it contributes significantly to the fishery from Massachusetts to North Carolina (Lux, Poole and Hamer, 1962).

Throughout its range, adult summer flounder leave bays and inshore ocean waters in the fall (Bigelow and Schroeder, 1953). There is evidence from study of female gonads that in the Middle Atlantic States the major spawning period begins when the fish are at a depth of about 15 fathoms shortly after their departure, and it ends in early December when they may be in ocean depths of 55 fathoms (Murawski, 1963, 1964). The minimum size at which females spawn has been determined from these studies to be 370 millimeters. Information from wintering grounds off Chesapeake Bay reveals that spawning in southern waters terminates at the end of November (Eldridge, 1962).

Nothing has been published concerning the distribution of positively identified summer flounder eggs in the ocean, although stripped and fertilized eggs from fish collected in 30 fathoms off Manasquan Inlet, New Jersey have been described (Murawski, 1964).

Larvae and postlarvae have been reported in Narragansett Bay, Rhode Island from late July through January (Herman, 1959). Postlarvae have been recorded in mid-November in Block Island Sound

[1] This report was originally submitted to the Biological Committee of the Atlantic States Marine Fisheries Commission in September 1964. It was prepared under the direction of the Subcommittee for Fisheries of the Atlantic Bight. The author is indebted to the many fishery biologists in the U. S. Fish and Wildlife Service, the state organizations concerned with fish and game conservation, and the Sport Fishing Institute who assisted in literature search and criticized the manuscript draft. Without their assistance, the report would not be as complete as it is.

in New York, in November and December from the Manasquan River estuary in New Jersey, in December in ocean waters off southern New Jersey, from October through March in ocean waters off Virginia, from January through March in Chesapeake Bay and the bays and inlets of Virginia's eastern shore, and from December through April in Bogue and Pamlico Sounds in North Carolina (Deubler, 1958; Massmann, Norcross and Joseph, 1961, 1962; Merriman and Sclar, 1952; Murawski, 1963, 1964).

Laboratory studies have indicated that salinity, per se, influences the growth of summer flounder postlarvae, i.e., postlarvae grow more rapidly as salinity increases, so long as its upper limits are within the range of natural occurrence (Deubler, 1962). These studies indicate that growth would be optimum at salinities found in the lower reaches of estuaries.

The adult fish spend the winter at depths of 20 to 85 fathoms in offshore waters from Cape Cod to North Carolina (Nesbit, 1935; Pearson, 1932; Westman, 1946). Returns from tagged specimens indicate that fish which summer in New England and the Middle Atlantic States winter generally from off Delaware to Oceanographer Canyon, i.e., north of winter trawl fishery grounds for summer flounder which lie off Virginia and North Carolina (Hamer and Lux, 1962; Poole, 1962). Otter trawlers effectively fish these offshore grounds, for 50 per cent and more of the annual landings in Massachusetts and Virginia come from the winter trawl fishery (Eldridge, 1962; Poole, 1962).

In spring, the fish move inshore where they remain throughout the summer to feed upon a wide variety of organisms. In the bays of the Middle Atlantic States, their diet consists to a great extent of sand shrimp, juvenile winter flounder, blue-claw crab, opossum shrimp and northern pipefish (deSylva, Kalber and Shuster, 1962; Poole, 1964). Recaptures of tagged fish indicate that in this region summer flounder which spend the summer in an area tend to return to that area and also drift to the north and east in subsequent summers. For example, 51 per cent of the inshore returns in the summer of 1962 for fish tagged in New Jersey in 1961 were from New York and the New England States. The majority of the remainder were from New Jersey (Hamer and Lux, 1962; Murawski, 1964). In a like manner, 18 per cent of the inshore returns in the summer of 1957 for fish tagged in New York in 1956 were from the New England States, while 76 per cent came from local waters of New York (Poole, 1962).

Juvenile summer flounder are distributed in spring, summer and fall in inshore estuarine waters from Connecticut to North Carolina (deSylva, Kalber and Shuster, 1962; Moore, 1894; Murawski, 1963, 1964; Pearcy and Richards, 1962; Poole, 1961; Tagatz and Dudley,

1961). However, there is indication from published and unpublished reports that the primary nursery grounds for juveniles occur in the sounds of North Carolina, Chesapeake Bay, and bays on the eastern shore of Virginia (Deubler, 1958; Murawski, 1963, 1964; Pearcy and Richards, 1962). In North Carolina waters, there is evidence that juvenile fish (100 to 260 millimeters) overwinter to some extent in Pamlico Sound and inshore ocean waters. The majority of these immature fish appear, however, to move to deeper ocean waters in the fall of the year where adult fish are found. Limited information suggests that in the more northern part of the range all juveniles spend the winter in the deeper ocean waters.

There has been no study of racial stocks over a wide geographic range of the summer flounder by meristic, morphometric or biochemical analysis. Published and unpublished reports of racial studies in the limited range of Maryland, Virginia and North Carolina waters suggest the need for additional research. Although there are indications of a meristic character that populations from Chesapeake Bay and from the vicinity of Beaufort, North Carolina belong to two different stocks (Ginsburg, 1952), unpublished investigations found no real differences in populations in locations where Ginsburg's study suggested a mixing of southern and northern populations.

Two studies of age and growth differ in the interpretation of age based upon rings which appear on the otolith (Eldridge, 1962; Poole, 1961). Eldridge's conclusions agree with those of Hildebrand and Schroeder (1928) who estimated from length-frequency data that flounder attain a size of 150–180 millimeters at age one and 200-260 millimeters at age two. The two studies using otoliths do indicate, however, that females grow faster than males and that summer flounder are recruited into the sport and commercial fisheries at a relatively young age, i.e., 3 years or less.

Length-weight relationships have been determined for male and female summer flounder taken off the New England States, off Virginia and in New Jersey waters (Eldridge, 1962; Lux and Porter, undated; Murawski, 1964).

A difference in maximum size of the sexes has been noted from winter trawl catches off New Jersey and Virginia (Eldridge, 1962; Murawski, 1963, 1964). In both areas the maximum length attained by males was approximately 550–600 millimeters; for females, 800 millimeters. Males were represented in 50 per cent or more of samples of fish less than approximately 400 millimeters long. In Great South Bay, New York, significantly more females than males occurred in trawl samples (Poole, 1964). Such sex ratio and size data suggest that any one or a combination of the following may be responsible: a higher mortality rate for males; a general growth limit of about

400 millimeters for males; a difference in habitat preference between the sexes; selective fishing gear; or sex reversal among males.

Most of the commercial catch of summer flounder is taken by otter trawl. In recent years, landings by the commercial fishery have increased. Annual landings in Virginia since 1944 have been over 1,000,000 pounds and in one year were as high as 2,746,000 pounds (Eldridge, 1962). Prior to 1940, annual landings in Virginia were below 900,000 pounds, often less than 500,000 pounds. In the New England and Middle Atlantic States, landings have increased steadily (except for the period during World War II) from 7,140,000 pounds in 1938 to approximately 15,000,000 pounds in the late 1950's and early 1960's (from Fishery Statistics of U. S. Dept. Interior). There is some indication that this increase has been the result of increased fishing effort rather than greater abundance of the fish (Perlmutter, 1959).

The sport fishery as well as the commercial fishery is effective in catching summer flounder in bays and inshore ocean waters (Briggs, 1962; Buller and Spear, 1950; Westman, 1946; Younger and Zamos, 1955). In Great South Bay, approximately 20 per cent of the population present in the bay was caught by hook and line each summer during 1956, 1958 and 1959 (Poole, 1962). Catch statistics give evidence that the sport catch in the Middle Atlantic States is higher than in the southern states (Briggs, 1962; Richards, 1962). In 1959, for example, Virginia's sport catch of summer flounder in Chesapeake Bay was 431,000 fish, and in the same year 1,643,000 were caught by sport fishermen in Great South Bay.

Current knowledge of the summer flounder and its fishery consists of catch data, length-weight relationships and findings from a few studies of life history. Some of this information is useful in describing the fishery, but to a great extent the data provide little that is necessary for evaluating the fishery's effects upon the resource. Since the history of the fishery for summer flounder indicates that demand for this fish will continue to be high, there is a need to obtain certain basic information. Of particular importance would be: (1) racial studies, initially limited to meristics; (2) a study of larvae and postlarvae by ocean sampling from Nantucket to Cape Hatteras to delineate the early nursery grounds; and (3) a cooperative study of the migratory patterns of immature summer flounder with exploratory efforts confined initially to Pamlico Sound and other appropriate areas of North Carolina.

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GENERAL NOTES

MARKING BROWN TROUT FRY WITH THE DYE, SUDAN BLACK B[1]

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Fish measuring 2 inches or less in length can usually be marked only by methods which do not involve handling. As a result, techniques to provide identification must be chemical in nature. Most of the recent methods of marking small fish have been described by Arnold (1965) and, in general, involve the feeding of, immersion in or, rarely, injection of dyes, drugs, metals or radioactive substances.

In brief, radioactivity, activation and metal deposition have been caused by all three methods but have provided marks which are difficult to detect in small fish although they might last for the fish's lifetime in some instances. Several tetracycline drugs and dyes applied by feeding and immersion have produced fluorescent conditions in small fish for periods ranging from a few hours to 3 months in one instance. One fluorescent dye was applied by spraying. At least six immersion dyes have provided identifiable marks lasting from several hours to a few weeks. Four substances have been reported to give 4-year marks when injected into tiny lamprey larvae, but injection is an almost impossible method on small fish. At least three nonfluorescent dye substances, among them Sudan Black B, have been fed to color fish for periods ranging from days to months. These techniques and their resulting marks are imperfect in a number of respects including difficulty in application of treatment, difficulty in detection or too short duration of mark, and mortality.

In the present study, Sudan Black B (Colour Index No. 26150) was fed to several species of fish and produced blue coloration lasting up to 8 months in certain fish (Loeb, 1963; Loeb *et al.*, 1961). The dye must be fed for from 1 day to several weeks to produce coloration which appears to vary in duration depending upon the species and size of fish, the water temperature and even the lot of the chemical. Blue coloration stands out well on fish and possibly does not attract predators to the extent that red, orange or yellow marks do.

Both fingerling and yearling brown trout (*Salmo trutta*) were marked with Sudan Black B by feeding the dye for 4 days. In these tests (Loeb, 1963) some yearlings, held at 47° F., maintained some coloration for 7 to 8 months, whereas the fingerlings, held at 67° F., maintained their coloration for only 5 to 6 months. It was hypothesized that the higher temperature resulted in a shorter period of coloration because of higher metabolic rates. However, an additional experiment involving small fish indicated that factors related to size might also have played a part.

Four thousand brown trout fry, averaging 4,025 per pound, were divided equally into a lot to be dyed and a control lot. Feeding was usually done twice a day for dyed fish and slightly oftener for controls. The dyed lot received ground liver containing 0.5 per cent Sudan Black B thoroughly mixed, while the controls received liver only. Water temperatures in the troughs ranged from 42° to 45° F. and averaged 44° F. Both lots fed well. The controls showed faster growth, running 1,507 per pound 54 days after the start of the test as compared with 1,816 per pound for the dyed fish. The test lasted for 120 days at which time an outbreak of disease forced it to be terminated. Until that time the controls, for reasons unknown, showed a slightly higher mortality than the dyed fish.

The history of coloration was as follows. For 2 weeks the presence of blue feces and swollen, blue bellies showed that the dyed fish were feeding well. At 16 days a few appeared to be slightly blue. At 22 days all were darker than the controls and about 1 per cent were distinctly blue. At 31 days all were blue but only a few were highly colored. At 50 days 95 per cent were a bright, light blue, and at 52 days, the last day the dye was fed, all of the fish except for a few runts were a deep blue throughout. This coloration was apparent 3 days later. However, 12 days after cessation of dye feeding (regular food was continued after the 52nd

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R. The histological work was done by Neil F. Ehlinger, senior fish pathologist of the Conservation Department.

day) the fish appeared to be less blue, and 6 days later 85 to 90 per cent of the fish had little or no color.

It had been hoped that fry would maintain the blue coloration for several months, especially in cold water. For some reasons, among which might be higher metabolic rate, higher ratio of surface area exposed, etc. as the fish developed, the blue coloration disappeared in too short a time to be useful for any but limited studies.

A histological examination of three of the dyed and three control fry (the dyed fish were killed 21 days after cessation of dye feeding) showed minor differences between the two lots. For example, the livers of the dyed fish exhibited a denser parechyma; the undyed, a tendency toward vaculation. The cytoplasm of the pancreas cells of the dyed fish was extremely acidophilic in response to staining. Also, a greater tendency toward cytoplasmic granulation was evident in the dyed specimens; this latter difference could well have been related to the differential intake of food between the two lots of fish. Such differences could occur in normal fish of the same population, and, because of the small sample size, are not considered to be statistical evidence of toxicity of Sudan Black B. However, when these findings are considered together with its known effects on carp (Loeb, 1963) and gull eggs (Wetherbee *et al.*, 1964), this dye must be considered somewhat deleterious or toxic. Most oil-soluble dyes are to some extent.

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CEMENTUM LAYERING IN THE CANINE TOOTH OF A 28-YEAR-OLD CAPTIVE BLACK BEAR[1]

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In studying the possibility of determining the age of black bears (*Ursus americanus*) from cross sections of the canine teeth, Sauer *et al.* (1966) examined teeth from captive bears up to 8 years of age that had been held in zoos. But they found no consistent pattern that could be related to age, presumably because such animals have a generally constant level of nutrition. Also these bears had lived under conditions where denning did not occur regularly, if at all.

Recently there has been opportunity to examine the canine tooth of a 28-year-old female bear that had been held in a private zoo at Actinolite, Ontario, where the winter climate is more severe than that at any of the localities from which the previous specimens had come. The bear's cage was provided with a den, and the animal had denned for from 3 to 4 months each year.[2]

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R. The authors are grateful to Blair Dawson of the Ontario Department of Lands and Forests for obtaining the loan of the skull and for permission to section the canine tooth. Thanks are also due William Goodrich of the New York State Health Department who cut the section and took photomicrographs of it.

[2] N. D. Patrick of the Ontario Department of Lands and Forests, personal communication.

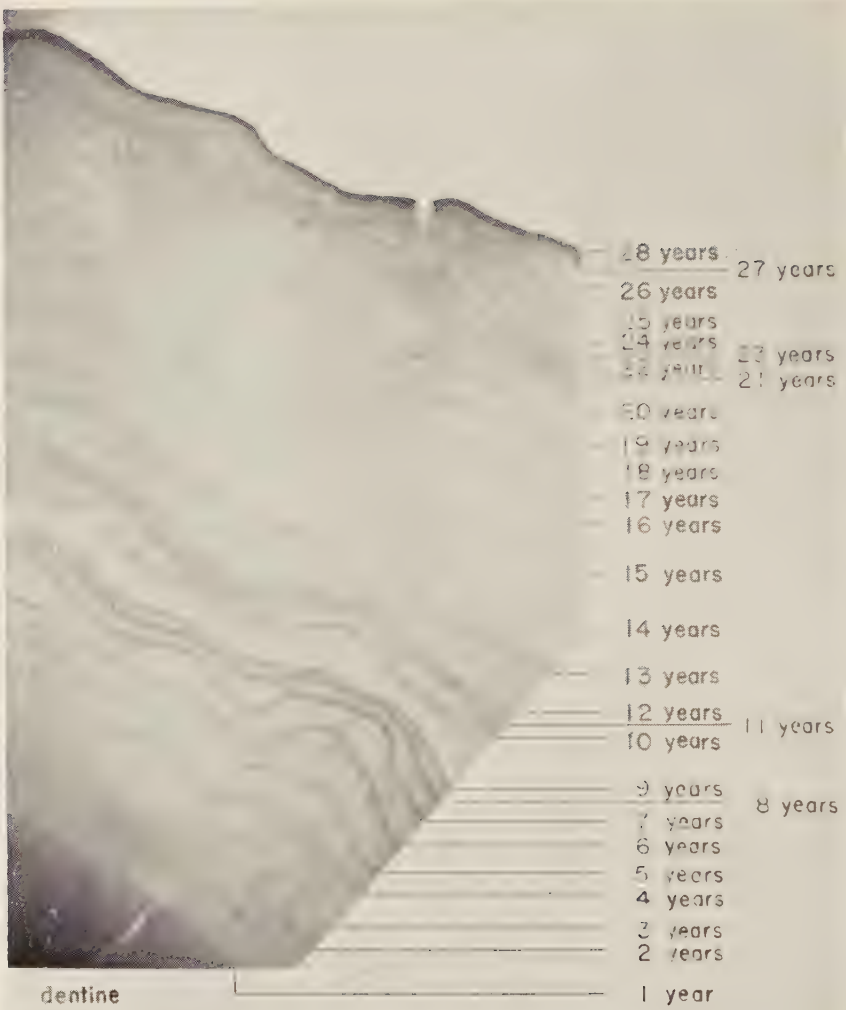

Figure 1. Segment of cross section of canine tooth (×6.3) from a 28-year-old captive female black bear.

A cross section of this tooth, prepared as described by Sauer *et al.* (1966), is illustrated in Figure 1 and shows 27 layers in the cementum. This constitutes further evidence that the alternate wide and narrow layers found in the cementum of canine teeth from wild bears reflect an annual periodicity in the animal's level of nutrition. Each wide translucent layer is formed during the spring, summer and fall when the bear feeds, and the narrow opaque layers are formed during the winter when it dens and fasts. That the tooth section from this bear, which was known to be 28 years old and denned each winter, exhibits 27 layers supports the hypothesis that the first wide translucent layer of cementum is deposited during the second summer of a bear's life and that subsequent layers are deposited annually after that with an intervening narrow opaque layer being deposited each winter.

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OBSERVATIONS ON TAGGING NORTHERN KINGFISH[1]

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Between August 1961 and October 1963, 213 adult (one year old or older) and 20 young-of-the-year northern kingfish (*Menticirrhus saxatilis*) were tagged and released at several locations on Long Island, New York. The adults, ranging in size from 225 to 405 millimeters, were captured in the ocean surf near Smith Point Park on Great South Beach with a 1,300-foot modified commercial haul seine. The young of the year, ranging in size from 130 to 225 millimeters, were taken with a 300-foot haul seine at Mercer's Island in Great South Bay and at Red Creek on Peconic Bay. All were retained in a canvas holding tank (4 feet long by 2½ feet wide by 3½ feet deep) prior to tagging and were provided a constant supply of running water by the method described by Schaefer (1965a). Each fish was tagged with two Petersen disks, one red and one white, affixed to the body by means of a 1¾-inch nickel pin. The tag was placed on the fish approximately one-half inch below the dorsal ridge and midway between the first and second dorsal fins. A one dollar reward was offered for the return of each tag.

Two tags were returned. One was from a 345-millimeter adult (sex not determined) tagged on May 8, 1962 and captured in a commercial haul seine four days later at Amagansett approximately 40 miles east of the release location. The other recovery was a tag placed on a 240-millimeter adult male on May 28, 1962 and subsequently found lying unattached on the beach adjacent to the tagging site in September 1963. It is believed that the fish bearing the latter tag died soon after release and was washed ashore in the area where the tag was eventually discovered.

Visual observations made during the tagging operations suggest that the northern kingfish is an extremely difficult species to maintain in captivity, even for a very brief period. For no apparent reason other than handling, many fish taken in good condition and placed in the holding tank soon entered a state of rigor (while yet respiring), as if suffering from severe shock. Some died in the tank before they could be tagged. Distress symptoms were also observed in many individuals released to the water following tagging. It is presumed, therefore, that post-tagging mortality was very high.

Similar holding problems have been experienced by other investigators working with fish of the same genus. Linton[2] failed on six separate occasions to maintain specimens of *M. littoralis* and *M. americanus* in temperature-controlled water at the laboratory. He reported that approximately 75 per cent of his specimens died after 2 days and the remainder died within 1 week. Fish (1954) reported that she was unable to hold five specimens of *M. saxatilis* long enough to acclimate them to laboratory conditions. Moreover, it is of considerable interest to note that Schwartz (1964) found *M. saxatilis* to be among the first of 15 species of marine fishes to succumb (survival times of 9 and 10 days, respectively, for the two specimens held) while held in captivity and subjected to natural winter water temperatures. The latter author also recorded that "no struggles were noted prior to death". A similar phenomenon was witnessed in laboratory aquaria by Perlmutter.[3]

That some survival has been obtained for tagged fish of this genus is evident, however, from recent experiments involving small numbers of *M. americanus* and *M. littoralis* in Florida (Ingle *et al.*, 1962; Topp, 1963; Beaumariage, 1964). Combined results for the period December 1960 to September 1964 indicated returns of 13.0 per cent for *M. americanus* and 9.5 per cent for *M. littoralis*. One specimen of *M. littoralis* was at liberty for 218 days before recapture (Beaumariage, 1964). Also, for California corbina (*M. undulatus*) tagged as mentioned by Carlisle *et al.* (1960), Fitch[4] reported that, of 882 specimens, 30, or 3.4 per cent, were recaptured after from 1 to 431 days (average was 44.9 days), one being taken 51 miles from the release site.

Based on the observations made during the present study, and on the apparent

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R

[2] Thomas L. Linton, personal communication.

[3] Alfred Perlmutter, personal communication.

[4] John E. Fitch, personal communication.

rapid growth rate, high mortality and short lifespan of *M. saxatilis* (Schaefer, 1965b), it is recommended that for any future tagging experiments on this species:

1. only young fish be tagged, preferably one year olds;
2. the fish be taken from areas other than the turbulent environment of the ocean surf;
3. a tag more suitable than the Petersen disk type be employed, perhaps one similar to the wire dart tag being developed by Eipper (1965) for use on small fish;
4. the fish be anesthetized;
5. extreme care be used in handling the fish at all times between capture and release;
6. a recovery tank, in addition to the holding tank, be provided so that the tagged fish can recuperate and be observed for a reasonable length of time prior to release.

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A PUGHEADED TAUTOG[1]

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Pugheadedness is an anomaly that has been reported in many species of fish (Mansuetti, 1960; Dawson, 1964; Alperin, 1965; Cheek, 1965; Isaacson, 1965), but, as far as the author can determine, it has not previously been reported in the tautog (*Tautoga onitis*). On May 27, 1965 while collecting sport fishing statistics, the author observed a pugheaded tautog taken in Little Peconic Bay on Long Island (N. Y.). The fish, a mature female, measured 382 millimeters total length, weighed 36 ounces and was judged to be 9+ years old. It exhibited typical pugheadedness (exopthalmic eyes, shortened and broadened maxilla, steep forehead, pushed in snout, incomplete closure of the jaws and an extended mandible). The stomach was empty. Other internal organs appeared normal.

Comparison with a length-weight equation for tautog derived by the author from measurements of 1,003 specimens showed that a fish 382 millimeters long should weigh approximately 43 ounces. Cooper (personal communication), using data from Rhode Island waters, found the average total length of 9-year-old females to be 390 millimeters with 95 per cent confidence limits of 378 to 402 millimeters. This fish fell well within those limits.

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[1] The author gratefully acknowledges the assistance of Dr. Richard A. Cooper of the U. S. Fish and Wildlife Service Biological Laboratory at West Boothbay Harbor, Maine in determining the age of this specimen.

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